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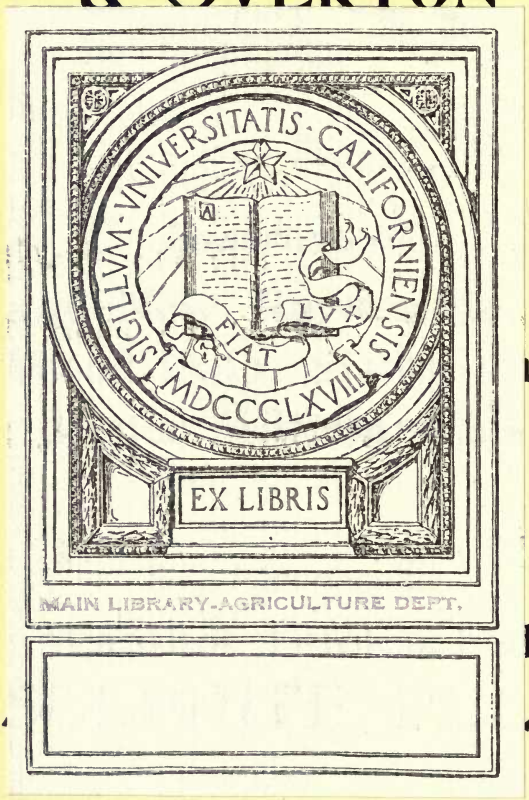

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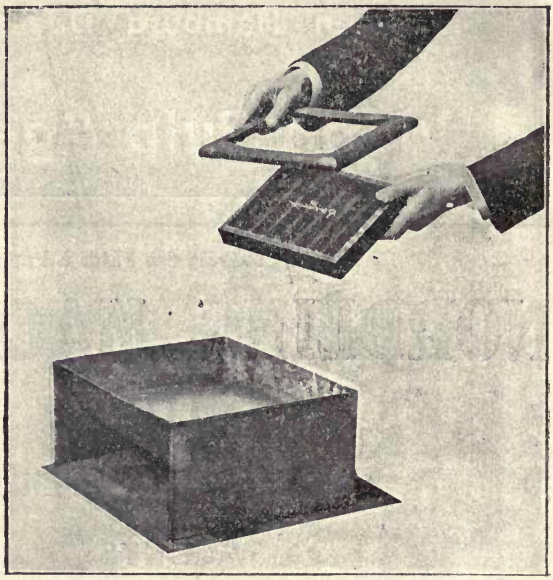

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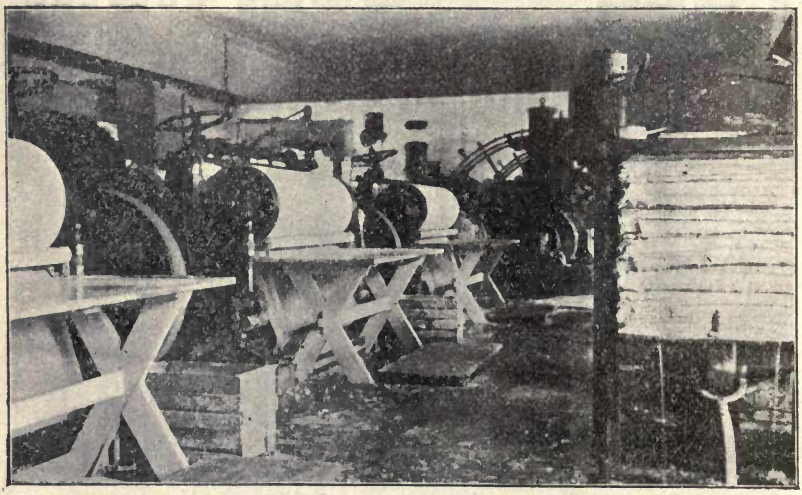

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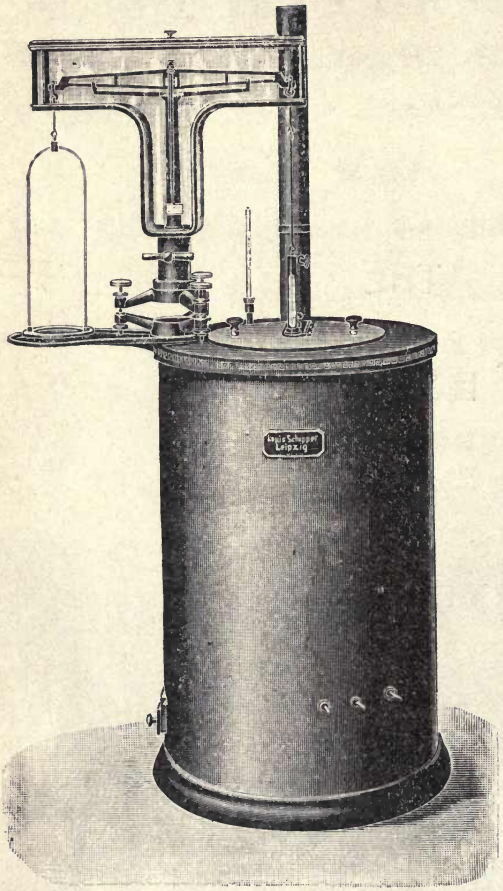

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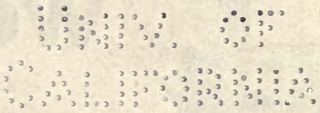

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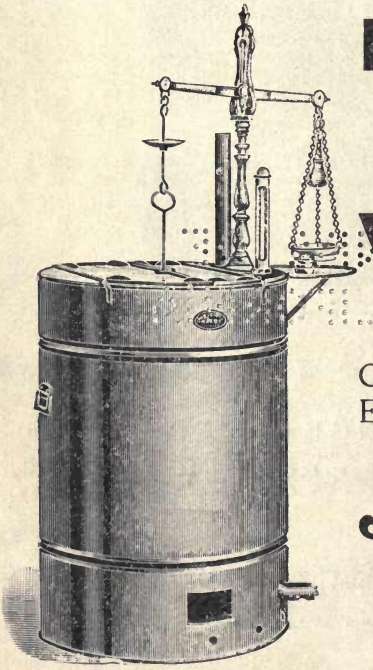

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PREFACE.

A GROWING demand for a simple handbook on the testing of wood pulp has led the authors to publish in convenient form an elementary treatise on the subject, embodying the results which have been obtained by leading analysts, and some descriptions of the methods now employed in various countries.

The book is divided into two sections :—

(1) The sampling and testing of pulp for moisture.

(2) The testing of wood pulp for its bleaching qualities.

An Appendix has been added which will be appreciated by all consumers of Wood Pulp, namely :—

The Chemistry of Bleaching.

The Authors desire to acknowledge the kindness of Messrs. Stonhill & Gillis for permission to reprint many articles contributed by them during recent years to the *World's Paper Trade Review*, and also to acknowledge a similar favour from Messrs. Marchant Singer & Co. in respect of one or two articles from the *Paper Makers' Monthly Journal*.

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PART I.

THE SAMPLING AND TESTING OF WOOD PULP FOR MOISTURE.

I. Introductory.

THE subject of Wood Pulp Testing seems to have attracted the general attention of paper makers about 1890, when correspondence on the methods of calculation of moisture was started by interested parties. One of the earliest discussions on the subject appeared in the *Chemical Trade Journal* of September 7th, 1889, under the heading of "Water in Wood Pulp." This contribution dealt more particularly with the method of calculating percentage of air dry pulp and also with the presence of water in the consignment of pulp delivered to the mill.

The subject, however, aroused considerable interest some years previous to this date, for in the *Papier Zeitung*, of June 24th, 1880, there is an interesting reference to a meeting of the German wood pulp firms, when the matter was fully discussed and a circular prepared for the use of paper makers and wood pulp manufacturers.

The circular goes on to show that even at this early date opinions varied considerably amongst paper makers and others as to the best method of finding out the dry contents of various pulps. The committee pointed out that there were many and frequent complaints as to the air dry contents of deliveries resulting in much unpleasant correspondence, and this led them to submit in certain terms what they considered the only correct system by which the percentage of moisture could be determined in goods sold in a moist condition.

The definition "air dry" was universally accepted as the

final weight of the material in question after it had been exposed sufficiently long in the open air to remain constant in weight. It was, however, pointed out that this method of testing could not be considered reliable because of the great variations in the atmospheric conditions according to the time of year, and therefore it was necessary to define such conditions for the testing as would produce a correct and uniform result.

It was suggested to dry the material in an oven at 100° C., to determine in this way the absolute dry weight of the pulp and to calculate the air dry weight by assuming that 88 parts of absolute dry pulp would be equivalent to 100 parts of air dry pulp.

The importance of the fixed temperature for drying was also emphasised in view of the fact that any higher temperature would result in loss of weight due to the dispersion of constituents other than moisture.

The necessity of taking samples from various bales and at the same time from different places in the same bale was further suggested, and also the necessity of taking into account the gross weight of the bales selected for sampling.

It was agreed at the meeting of the manufacturers that from every tenth bale produced on the machine a sample of 100 grams should be cut, marked with the number of the bale, and subsequently dried at 100° C. until the weight was perfectly constant at that temperature.

The absolute dry weight so found was to be the basis of calculation on the assumption that 88 parts absolute dry weight equalled 100 parts air-dry.

The committee appointed to look into this matter expressed the opinion that such was the correct method, and suggested that their readers should give the matter their most careful attention.

In Hoffman's "Handbuch der Papierfabrikation" an apparatus specially constructed for drying pulp and other paper-making materials is fully described, the apparatus having been devised by Professor Kirchner in the year 1876.

It may be taken for granted, therefore, that the subject of the testing of wood pulp dates from about 1875, not many years after chemical wood pulp was being used in considerable quantities in many of the paper mills in Europe.

It is curious to notice that the discussions on the testing of wood pulp centered mainly on the methods of calculation and the nature of the so-called 10 per cent. of moisture, since some paper makers added 10 per cent. to the absolute dry weight and assumed that this was the correct method of arriving at the air-dry weight of pulp. The difficulties arising out of the meaning of 10 per cent. have long since disappeared owing to the simple method of expression now customary on wood pulp certificates, namely, that "90 parts absolute dry weight is equal to 100 parts air-dry weight."

It is rather amusing to go back over the files of the trade journals from 1880 to 1890 and notice the elaborate calculations then published on such a simple question, for example, as that shown in the following:—"Does 12 per cent. atmospheric moisture mean that 100 lbs. of pulp contains 12 lbs. of water and 88 lbs. of dry pulp, or that 112 lbs. contains 12 lbs. of water and 100 lbs. of dry pulp?"

The more important question of the actual methods of drawing samples was not fully discussed until a later date, the subject being first ventilated in a journal entitled *Wood Pulp.*

II. The Selection of Bales.

THE examination of wood pulp for the purpose of determining the exact air dry contents of a consignment is an important operation which is a necessary factor in the work both of the pulp manufacturer and the paper maker.

It is generally conceded that the chief difficulty in arriving at the true weight of dry pulp occurs in the process of sampling, since the operation of drying out the sample itself is an easy matter under the conditions usually accepted.

But in the matter of sampling, the problem is complicated by the enormous bulk of the material, the variation likely to take place during the manufacture of the pulp, and the disturbance of the uniformity of moisture in individual bales by exposure to air or water.

Object of the Testing.—The consignment of pulp is tested at the paper mill in order to determine the exact air dry contents, this being a fixed definite quantity whereas the gross weight may be varied by exposure to rain or high seas during transport, giving an increase of weight; or by exposure to air and sun in the warehouse which diminishes the gross weight.

Quantity to be Sampled.—In general practice 3 or 4 per cent. of the number of bales in a consignment is ample for a thorough and reliable test. The quantity, however, is to some extent determined by the condition of the pulp.

It is obvious that if the whole of the pulp has been carefully weighed and fastened up at the wood pulp manufactory, so that on its arrival at the mill the weights of individual bales do not vary much or only within certain allowable limits, the gross weight of the whole parcel can be accurately gauged with a much smaller number of separately weighed bales than with pulp carelessly packed and exhibiting considerable differences in the weight of different bales. In this case the percentage necessary for a good test must be larger. For example, if 10 bales each weighing approximately 2 cwt. vary

by only 1 or 2 lbs., the heaviest bale being 2 lbs. over and the lightest bale 1 lb. under, then the accuracy of the calculated weight of the parcel is far greater than with the weight determined on 10 bales varying by 20 lbs., where perhaps, the heaviest is 10 lbs. over and the lightest 10 lbs. under the average weight.

The same arguments apply to the question of variation in moisture. With a good well-packed uniform pulp, showing only small variations in moisture, 1 per cent. of the parcel might give a result identical or nearly so with 5 per cent. or 10 per cent., whereas in a badly made pulp showing considerable differences in moisture the test may be uncertain with 5 per cent. or even 10 per cent.

Example.—Taking the case of a parcel invoiced at 50 per cent., in which three tests are made as follows:—the gross weights of all bales, for the sake of simplifying the figures, being taken at exactly 2 cwt.

Test 1.—47·2 on 2 per cent. of the parcel.
Test 2.—51·4 on another 2 per cent.
Test 3.—49·3 on another 2 per cent.

Mean 49·3

The exact result in the above example is evidently a matter of some uncertainty, and the only remedy is a repetition of the tests. But variations of this character are due to causes which are to a large extent preventable, and it is only reasonable to suppose that the pulp manufacturer would control the operations in the mill so as to ensure a greater uniformity in moisture.

Experience has shown that with properly made uniform pulp, containing a definite weight of moist material when first packed, 2 per cent. of the number of bales gives a reasonably good result, and this quantity is now generally accepted by buyers and sellers.

Another point to be noted in connection with the pulp drawn from the consignment for testing purposes, in reference to the quantity sampled, is the method of taking the bales. Where pulp can be sampled as drawn from barges, railway trucks, or other conveyances, it is best to take the given number of bales fairly distributed over the parcel. Thus, if 20 bales are determined as the requisite quantity to be

sampled while the parcel is being put into stock, it is far better to take one bale out of every 40 or 50 thus stocked until 20 have been put aside and collected, than to put aside the first or last 20 bales which are unloaded. In this way a more accurate test will be obtained. This is especially necessary in the case of badly packed and varying pulp.

In normal cases when the consignment is of an average character, the bales of pulp in being transferred, first from mill to warehouse, then into the ship, and subsequently into barges and finally to the paper mill, get well mixed.

This is a matter of common knowledge shown by the fact that if the bales have been numbered when manufactured, the first 20 taken at random at the final destination will show varying numbers, well distributed. With a large consignment this will not always occur. Thus in an actual case, examining a large cargo of about 1,500 tons, we obtained varying results, of which the following may be quoted ;—

Test 1.—On 36 bales selected from the first 100 tons delivered. Average dry weight per bale 213·77 lbs.

Test 2.—On 36 bales selected from the cargo being unloaded after half the parcel had been put in stock. Average dry weight per bale, 218·12 lbs.

Test 3.—On 36 bales selected from the cargo when the whole quantity had been delivered. Average dry weight per bale, 205·33 lbs.

III. Methods of Sampling.

MANY methods of sampling wood pulp have been devised from time to time, but with larger experience certain systems have been accepted as correct, based on reasonable assumptions as to the proper conditions for the selection of bales and also of the sheets from the said test bales.

Selection of sheets.—The most essential point to be considered in the examination of the bales is the selection of the sheets from which the samples of pulp are ultimately to be cut. It is obvious that in the case of freshly made pulp sampled immediately it has been taken from the hydraulic press in the pulp mill, the selection of sheets is a comparatively easy matter, as almost any sheet drawn from the bale represents the whole bale. When the pulp, however, has been kept in stock for any length of time or transhipped to the paper mill the conditions are quite altered. The moisture is no longer evenly distributed through the bale, the outer sheets exposed to air having lost weight considerably through the evaporation of moisture.

The selection of the sheets to ensure an accurate sample from the bale is a matter of importance and the difficulties of sampling are greatly increased in consequence.

Various methods are adopted by analysts, of a more or less empirical nature, and it is not easy to lay down any set rules, some operators preferring to take samples from only three sheets and others contending that five, six, or even ten sheets should be taken from each bale. Much depends upon the state of the pulp, since pulp despatched to a mill in England, immediately it has been manufactured, does not suffer changes in condition to the same extent as pulp kept in stock for several weeks or months.

The question may be studied by means of figure I. in which are set out diagrams representing the various systems of selecting sheets.

Method A.—The diagram represents the end view of a bale having a height H. The bale is divided into five sections having the respective heights shown in the diagram, namely, h, $2h$, $2h$, $2h$, h. The bale is thus divided into four equal volumes, represented by the height $2h$. It will be observed that the fourth section itself is divided into two portions represented by the top and bottom sections marked h. The positions of the sheets to be drawn for sampling, taken from the centre of each of the five sections, are indicated by the dotted lines.

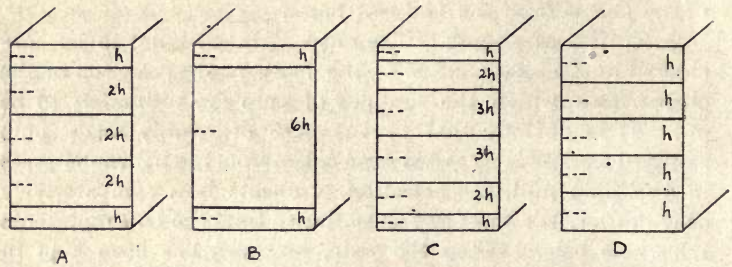


Fig. I.—Showing Methods used in selecting Test Sheets.

Method B.—The diagram represents the end view of a bale having a height H. The bale is divided into three sections having the respective heights shown in the diagram, namely, h, $6h$, h. The bale is thus divided into three volumes represented by the heights h, $6h$, h. The centre volume contains six times the amount of pulp contained in the two outer sections. In this case three sheets are selected, one from the centre of each of the sections.

Method C.—The diagram represents the end view of a bale having a height H. The bale is divided into six sections having the respective heights shown in the diagram, namely, h, $2h$, $3h$, $3h$, $2h$, h. The bale is thus divided into six sections having the proportional volumes shown in the diagram. In this case six sheets are taken, one from the centre of each section as indicated by the dotted lines.

Method D.—The bale is divided into five equal sections represented by the height *h*, the total volume of the bale being equivalent to *H*. The centre sheet of each section is withdrawn for sampling as in the other cases.

Method of Sampling the Selected Sheets.—In the United Kingdom the sheets are almost universally sampled either by means of *diagonal strips* cut across from corner to corner or by means of *wedges*.

In the former case an equal volume of pulp is taken from each of the selected sheets represented by a strip about one inch wide.

In the *wedge* system the samples are so cut that the wedge drawn from the sheet is proportional to the volume of pulp which it represents. This may be shown by stating a case.

Thus, in method B the wedge which represents the large central portion of the bale should be six times the size of the wedge drawn from the top section *h*. There are serious objections, however, to taking one large sample in this way from the centre of the bale.

The systems which appear to be most suited to the testing of bales which have become excessively dry on the outside are method A and method C, since the outer portions of the bale are properly sampled as well as the intermediate portions lying between the centre and the outside of the bale.

General Principles.—It is safe to assume that under normal conditions moist pulp arrives at the paper mill with its gross weight more or less reduced by evaporation of moisture from the outside of the bales, particularly if it has been stocked for several weeks before shipment.

Thus the centre of each bale probably contains the pulp little changed from its original state, and the percentage of moisture is found to be less in regular proportion towards the outside sheets. In testing it becomes necessary to select samples from the bale in such a way that each successive portion from the centre to the outside is adequately represented. In methods A and C this principle is properly recognised.

In the case of method A the wettest section of the bale is the centre piece 2 *h*. On each side of this section are two others drier than the centre, but not so dry as the outer section *h*. Finally the drier portions are the small volumes *h*. The driest part of the bales are therefore correctly sampled.

In all attempts to reduce the question of sampling to a rigid system of selecting sheets and drawing test samples in a prescribed manner, it should not be forgotten that common sense and experience must necessarily be exercised in slight modifications called for by abnormal conditions which arise, particularly in respect of the excessive dryness or moisture of the outer sheets.

IV. The "Wedge" System.

THE advantage of the "wedge" as compared with a rectangular strip is to be found in the fact that the former is a

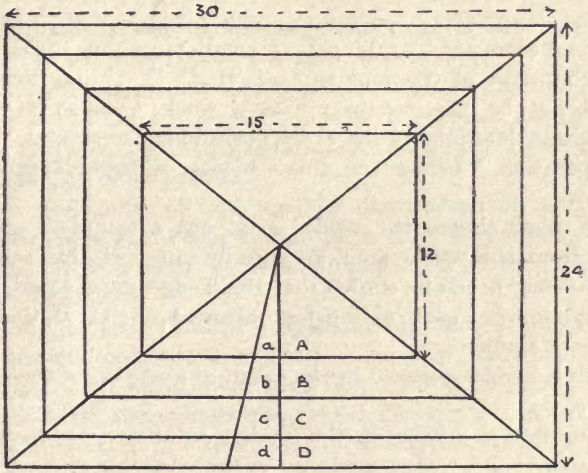


Fig. II.

true sample, mathematically at any rate, of the sheet of pulp from which it is cut, that is to say, it ensures the proper proportion of what Pulp Manufacturers call the inside and outside portions of the sheet of pulp. The exact relation of the wedge to the rectangular sheet of pulp which it is supposed to represent can easily be demonstrated. If a sheet of pulp measures 30 × 24 (*see* Fig. II.) it can be divided into four equal portions as follows:

A. the inside portion measuring 15 × 12
B. & C. intermediate portions.
D. the outer portion.

The division of the whole sheet into four equal parts requires that the area of each of the four sections A, B, C, D should be $720 \div 4 = 180$. Hence the dimensions of the various rectangles having their sides always in the proportion of 30 : 24 would be

Area A	$= 15 \times 12$	$= 180$
Area A + B	$= 21{\cdot}2125 \times 16{\cdot}97$	$= 360$
Area A + B + C	$= 25{\cdot}98 \times 20{\cdot}784$	$= 540$
Area A + B + C + D	$= 30 \times 24$	$= 720$

Since these areas are equal it would be possible to sample the sheet correctly by taking four small pieces of equal area, one from each of the four parts A, B, C, D. This, however, would not be possible in practical work, because it would necessitate determining the exact position of the several "lines of separation" before the small pieces of equal area could be cut.

The other alternative would be to cut a complete quarter sheet from the whole area, an equally impracticable scheme. If, however, it can be shown that the wedge gives equal sized pieces, one from each of the four areas A, B, C, D, then the matter is simple.

Such a wedge is shown in the diagram made up of the pieces a, b, c, d.

Assuming the base of the wedge to be 2·0 then the total area of the wedge made up of the sections a, b, c, d, is $\frac{1}{2} \times 12 \times 2 = 12$.

Similarly the area of the wedge represented by the triangle a is $\frac{1}{2} \times 6 \times 1 = 3$.

The whole wedge consists of a series of triangles (1) the piece a. (2) triangle consisting of the pieces $a + b$. (3) a triangle consisting of the pieces $a + b + c$. (4) the total wedge consisting of the four pieces $a + b + c + d$.

The heights of the various triangles are given in Fig. III., being calculated from the dimensions of the rectangles given in Fig. II.

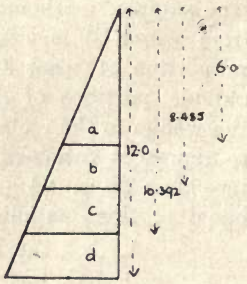


Fig. III.

If the base of the full sized wedge is taken at 2·0 then the base of each of the various triangles may be calculated, and from these dimensions the areas of the several triangles are also determined as follows:

Triangle.	*Area.*	
$a+b+c+d$	$= \frac{1}{2} \times 12 \times 2$	$= 12 \cdot 0$
$a+b+c$	$= \frac{1}{2} \times 10 \cdot 392 \times 1 \cdot 732$	$= 9 \cdot 0$
$a+b$	$= \frac{1}{2} \times 8 \cdot 485 \times 1 \cdot 41416$	$= 6 \cdot 0$
a	$= \frac{1}{2} \times 6 \times 1$	$= 3 \cdot 0$

From this it will be seen that the areas of the four pieces a, b, c, d, are equal, namely 3·0.

It may be noted that the objection which is sometimes taken to the use of the wedge, namely that it assumes the moisture to be fairly evenly distributed over the sheet, applies with equal force to any other system.

The probability of this unequal distribution of moisture is allowed for in the Wedge system as in other methods by taking the sample test pieces at different positions in the successive sheets sampled.

A suggested "Official" System.—In view of a decision of the special committee appointed in 1908 to consider the question of adopting a uniform method of drawing samples, a few notes on the subject may be of service to those who are not familiar with the method which was selected for experimental purposes.

The system was suggested by Mr. A. Bommen, of Christiania, and like all methods based on purely theoretical grounds and proposed as a practical solution of a serious difficulty, it is a praiseworthy attempt to reduce the whole question of sampling to a routine system. The merits of the system must, however, be judged in the light of practical experience. Objections have been raised on account of the fact that the time occupied in testing a certain number of bales is about 50 per cent. longer than that required by ordinary methods, but such an objection can surely have no weight if greater accuracy and uniformity in results are eventually secured. Whether such benefits will be derived from the introduction of this method can only be decided by repeated tests.

In testing six bales, for example, according to the new method suggested by Mr. A. Bommen, the procedure is as follows:—

To Select the Sheets.

From each bale take five sheets at equal distances apart, the distance being one-fifth of the height of the bale. These sheets are not to be selected from the same position in each bale, but are to be taken as shown in the diagram in such a manner that while the first sheet to be sampled in bale No. 1 is the top sheet of that bale, the first sheet to be sampled in bale No. 6 is the sheet situated one-fifth of the height of the bale from the top.

The exact position of the sheets can be found by measurement, thus:—Take a strip of pulp, or a wooden stick, in length equal to the height of the bale. Mark this off into five equal spaces. Divide the first space into six equal parts as shown in Fig. 2.

Bale No. 1.—Set the rod with the mark 1 level with the top sheet of bale No. 1. With a pencil mark the points I., II., III., IV., V. on the edge of the bale. Take the sheets so marked for testing.

Bale No. 2.—Set the rod with mark 2 level with the top sheet of bale No. 2. Mark off the points I., II., III., IV., V., on the edge of the bale. Take sheets so marked for testing.

Bale No. 3.—Set the rod with mark 3 level with the top sheet of bale No. 3. Mark off the points I., II., III., IV., V. on the edge of the bale. Take the sheets so marked for testing.

Bales Nos. 4, 5, 6.—Proceed in a similar manner.

Fig. 2 shows the position of the measuring rod as required for marking bale No. 4.

To Sample the Sheets.

From each of the five sheets selected out of each bale cut a wedge, using for that purpose the special template approved by the several Associations. The template as shown in Fig. 3 consists of a disc and rotating wedge, being employed in the following manner:—

Place the instrument on the sheet of pulp with circular disc exactly over the centre of the sheet, and the arrow head pointing exactly towards the middle of one edge of the sheet. The brass wedge can then be turned round to any position.

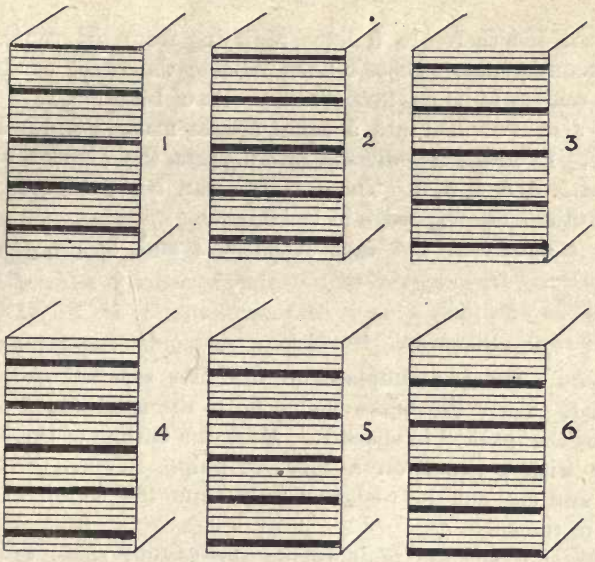


FIG 1

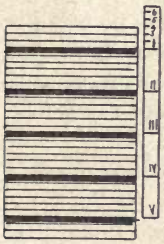


FIG 2

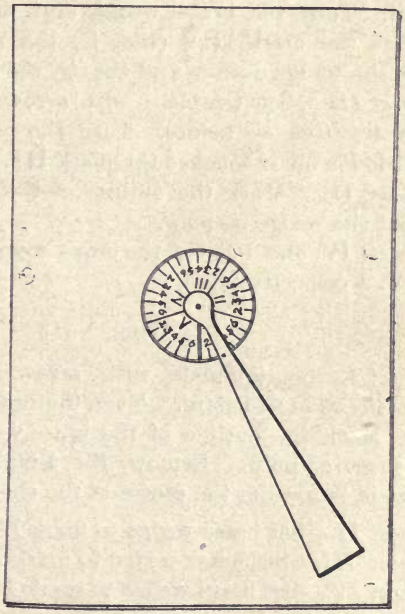


FIG 3

Fig. IV. Diagram illustrating the suggested "Official" System.

On the disc there are 5 lines radiating from the centre to the circumference. These 5 lines indicate the exact positions of the wedges to be cut from the 5 sheets of Bale No. 1.

The disc is divided into 5 equal spaces marked I., II., III., IV., V. Each space is divided into 6 parts, the division being marked 1, 2, 3, 4, 5, 6. These marks can be used for finding the positions of any wedge in the 6 bales.

For example in the case of bales 2 and 3 proceed as follows:—

Bale No. 2.

Sheet I.—Set the template on the first selected sheet as directed. Turn the brass wedge until the small index on it reaches the mark 2 in space I. Mark the outline of the brass wedge with a pencil on a sheet of pulp. Remove the template and cut out the wedge of pulp from the centre of the sheet to the edge.

Sheet II.—Set the template on the second sheet exactly as before, with arrow head pointing in the same direction as before. Turn the brass wedge until the small index on it touches the mark II. 2 (that is, the mark 2 in space II.). Mark the wedge outline and cut out the wedge of pulp.

Sheet III.—Set template with arrow head pointing in the same direction as before. Turn the brass wedge until the small index on it touches the mark III. 2 (that is, the mark 2 in space III. Mark the outline of the wedges as before, and cut out the wedge of pulp.

Sheets IV. and V.—Set the brass wedge to the marks IV. 2 and V. 2 respectively.

Bale No. 3.

Sheet I.—Set template with arrow head pointing in the same direction as before. Turn the brass wedge to the mark I. 3. Mark the outline of the brass wedge with a pencil on the sheet of pulp. Remove the template and cut out the wedge of pulp from the centre of the sheet to the edge.

Sheet II.—Set brass wedge to mark II. 3.

Sheet III.—Set brass wedge to mark III. 3.

Sheet IV.—Set brass wedge to mark IV. 3.

Sheet V.—Set brass wedge to mark V. 3.

In every case place the instrument on the sheet of pulp with the circular disc over the centre of the sheet, and with the arrow head pointing exactly towards the middle of one side, and always in that same direction.

The method may be easily understood by a few trials of the instrument.

When the 6 bales have been sampled, there will be 30 wedges in all to represent the 6 bales.

When the number of bales to be selected is more than 6, take 12, 18, 24 or more, equal to 2 or 4 per cent. of the consignment, and sample each 6 bales in the manner described.

V. Systems used in other Countries.

FRANCE.

DESCRIPTION KINDLY REVISED BY MONSIEUR PERSOZ, OF THE CHAMBER OF COMMERCE, PARIS.

Bales of Pulp packed in sheets.—According to the thickness of the bales, samples are taken from 8 to 12 sheets drawn at regular intervals, the first sheet being taken near the top of the bale and the others taken at equal spaces down to the bottom of the bale. Strips of uniform width, 2 to 3 inches, are cut from each sheet by means of a special instrument, which resembles a fork having two parallel knives (*see* fig. V.)

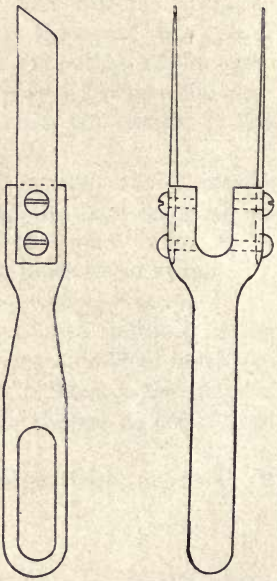


Fig. V.—Special Knife used in France.

Until quite recently these strips have been cut from the sheets alternately parallel to the long side and to the short side of the sheets respectively. This system has been for some time accepted by interested parties.

The laboratory of the Chamber of Commerce in Paris instituted comparative experiments in order to determine the relative value of the different methods of sampling. As a result of of these special experiments it has been decided that strips cut diagonally across the sheet give results of a more satisfactory character. That system has now been suggested as official for testing bales of wood pulp in preference to the former system. The experiments which have led Monsieur Persoz to recommend the cutting of diagonal strips have been fully described

in various French journals and particularly in *Le Moniteur de la Papeterie Francaise*, 1910, p. 517, *et seq.*

The strips taken from one bale form a sample which is at once weighed by the representative of the Chamber of Commerce on his own balance which he carries with him, and then carefully wrapped up and marked with the number of the bale from which the sample has been drawn.

Pulp in the form of Rolls.—The roll of pulp is slit down to the centre by means of a knife and strips are then cut from the edges of the sheets so produced at regular intervals from one another. Usually 10 strips are taken, those from the outer portion of the roll being cut wider than those taken near the centre of the roll.

Number of Bales selected for sampling.—Usually 2 per cent. of the number of bales may be considered sufficient for the purpose of sampling, but while this proportion is sufficient for consignments containing a large number of bales, it cannot be taken as accurate when the consignment contains a smaller number of bales. The following proportions seem to give better results :—

For consignments containing 200 bales or less,	10 per cent.
For consignments containing 200-1000 bales,	5 per cent.
Minimum number of bales to be sampled ...	20
Consignments of more than 1000 bales ...	3 per cent.
Minimum number of bales to be sampled ...	50

GERMANY.

In Germany, as in other countries, there is no recognised official method. Dr. Otto Winkler, of Leipzig, in his book entitled "Die Trockengehalts-Bestimmung der Papierfaserstoffe" gives the following methods as being customary in Germany :—

Bales packed in sheets.—The number of sheets selected for testing should be at least 5, taken from different parts of the bale at equal distances from each other.

Rolls of Pulp.—The roll is first cut through from top to bottom and down to the interior, thus splitting open the roll into a number of sheets.

Sampling the selected sheets.—In the case of moist mechanical pulp and dry chemical pulp the five sheets selected are sampled by means of strips cut parallel to the two sides of the sheet, these strips being 2 inches to 3 inches wide.

In the case of pulp in rolls, strips are taken from the cut edges of the roll prepared for sampling, the strips near the outside of the roll being cut somewhat larger than those near the centre, since the diameter of the roll is larger near the outside than the centre.

AMERICA.

The question of sampling pulp in America has been studied most carefully by Mr. Arthur D. Little, who has devised schemes for sampling dry bales or rolls of pulp without unfastening them as is customary in Europe. He states that the local conditions are such that this method of sampling is almost imperative, for the work has frequently to be carried out at the docks where the facilities for operating do not allow of the opening up of the bales. The following is the method as described by him :—

Pulp in Bales.—For sampling baled pulp we propose a disc method to be carried out as follows :—

By means of a special auger bit made for the purpose, or with a machine cutter using a single knife, a hole approximately 4 inches in diameter shall be bored into the bales to be sampled to a depth of 3 inches. The discs thus cut from the pulps shall be removed and ten of them taken as a sample, these to be selected as follows :—One disc shall be taken from the second sheet of the wrapper, two discs from a depth of 1 inch, three discs from a depth of 2 inches, and four discs from a depth of 3 inches. Ten per cent of all the bales in a lot shall be sampled, although in any case ten shall be the minimum number of bales sampled.

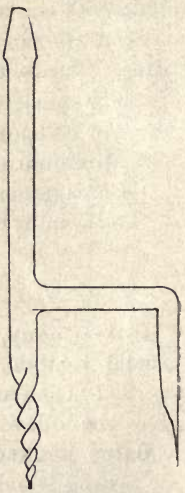


Fig. VI.
Disc Cutting Auger.

The holes to be bored shall be so located that in five successive bales they will represent a portion extending diagonally across the bale, the first hole to be bored at the corner, the edges of the cut being at the distance of 1 inch from the edge of the bale. The second cut shall then be made half way between the location of the first and the centre, the third at

the centre, and so on until the fifth bale is sampled in the opposite corner, in a position corresponding to the first.

Pulp in Rolls.—For rolled pulp a method similar to that described for bales shall be adopted. The position of the samples taken in this case, however, shall be determined according to the following plan:

The first sample shall be taken so that the edge of the disc shall be within one inch of the end of the roll, the second half-way between the first and the centre, the third at the centre, and so on.

Pulp in Laps.—For wet pulp in laps the samples shall be taken by cutting a strip about two inches wide from the centre of a folded section to the edge; the strips on four successive laps to be so taken that a sample representative of the diagonal of the sheet will be obtained. For the purpose of taking these samples, the sheets shall be unfolded and the samples taken, No. 1, from the first lap; No. 2 from the second lap; No. 3 from the third, and so on.

The number of laps to be sampled shall be not less than one in every 2,000 pounds of the wet pulp.

All samples immediately upon being taken shall be placed in a suitable air-tight container, from which they shall not be removed until after weighing. The samples shall then be dried in a suitable oven provided with good ventilation at a temperature of 212 to 220 degs. F. until successive weighings made after an interval of not less than three hours will show no further loss in weight. From the loss thus obtained the total percentage of moisture shall be calculated, and the difference between this and 100 per cent. will represent the amount of bone-dry pulp. Air-dry pulp is understood to consist of 90 per cent. absolutely dry pulp and 10 per cent. water. The percentage of air-dry pulp should, therefore, be calculated by dividing the bone-dry percentage by nine and multiplying by ten, or in other words, by adding one-ninth to the bone-dry test.

In 1909, Mr. Little reported fully to the American Pulp and Paper Association on this question of sampling, and the following extract is suggestive:—

"We have made a number of experiments during the past year to obtain data by which we could compare the methods of sampling baled pulp and arrive at one which would be both

fair and practical. The method which has been used in the speaker's laboratory for a number of years was adopted as giving as nearly as possible a proper proportion of pulp from the outside drier portion of the bale and the inner part, which had not been affected by surface drying.

" This method is as follows :

" By means of a special bit or disc cutter a hole is bored into the bale to be sampled to a depth of 3 inches ; and from the discs thus cut ten are selected, the first of these being the second sheet from the wrapper, the second being taken at a depth of 1 inch, the third at a depth of 2 inches, and the fourth from the innermost sheets cut. As this affords a rapid means of sampling baled pulp, it was deemed advisable, first of all, to make a number of tests to determine the accuracy with which the true moisture content of a bale is arrived at by this method.

" In one series of tests, the moisture content of the bales tested was accurately determined by taking a quarter sheet from every tenth sheet throughout the bale. The average of these, of course, gave an accurate measure of the total moisture content. These bales were tested at the same time by our own method and the average results compared as follows :—Disc method, 14·42 per cent. moisture ; quarter sheet method, 14·35 per cent. moisture.

" In another series of tests the moisture of the bale was determined by taking six quarter sheets : the first one being the sixth sheet from the wrapper and the others being selected at intervals of 1½ inches, towards the centre. In this instance the disc method gave an average figure of 14·79 per cent. for 20 bales, while the quarter sheet method showed a moisture content of 14·59 per cent.

" From these tests, it is evident that the results secured by our disc method are in close agreement with the actual moisture content of the bales, and we are, therefore, inclined to favour this method as being simpler, easier and quicker than any quarter sheet or other method which would involve opening the bales to be sampled.

" As bearing upon the proper points at which discs should be cut from the bales, it is of importance to know to what extent pulp will dry out from the edges of the bale and also how far in from the outside sheets the effect of drying will be noticed."

"With the first point in mind, 10 bales of pulp were selected, and a section of each about an inch in thickness was taken from near the middle. From one edge of these sections a block was cut approximately 12 inches long and extending 6 inches toward the centre. This was then at once divided into six parts, each 1 inch wide and representing the different stops in from the edge toward the centre of the bales. The average of these tests for the six 1 inch sections was as follows:—

First inch	...	...	13·3 per cent.
Second inch	...	...	15·2 „ „
Third inch	...	...	14·9 „ „
Fourth inch	...	...	15·1 „ „
Fifth inch	...	...	15·6 „ „
Sixth inch	...	...	16·1 „ „

"These figures indicate that in baled pulp practically no drying is to be noticed at a distance beyond 1 inch from the edge.

"In the cases of bales having a moisture content of less than 10 per cent. there was scarcely any drying to be noticed at the edges, while in bales running as high as 23 per cent. moisture content the difference was as great as 3 and 4 per cent. between this outer zone and the body of the pulp. In a bale of pulp 30 by 40 inches in size a little over 10 per cent. is included in the pulp in this outer zone, which is dryer than the remainder: and this fact should be borne in mind when deciding upon a method of sampling to truly represent the moisture content of baled pulp.

"Another series of tests was made to determine to what depth in a bale the drying from the surface would be materially noticeable. The results of these tests show that the drying is almost as great from the front and back as from the edges of bundles that are in any way exposed. The effect of the drying was noticeable throughout the first inch in thickness at either side of the bales and in some cases amounted to as much as 3 per cent. Below a depth of 1 or 1½ inches the moisture was found to vary in either direction and evidently was not affected by the surface drying. The proportion of the average bale thus dried out from the surface amounts to about 10 per cent. to 12 per cent., and this again must be considered in selecting samples for a test. The

method of sampling baled pulp must, therefore, be such that a suitable proportion of the sample taken shall represent the dryer portions of the bales.

"In taking samples by any quarter sheet method, no attention need, of course, be paid to the drying from the edges, as each quarter sheet selected will contain its proportionate amount of pulp from the dryer zone.

"Any method, however, which does not include a proportionate amount of pulp from the edges with every sample must be so designed that the dry portion of the bale shall be represented by a proper proportion of samples taken.

"It will at once be seen that our disc method provides for 10 per cent. of the sample being taken from the portion near the surface, where the greatest drying effect is to be noted. It is, of course, impossible to make one cut in ten entirely within the zone which is affected by drying from the edges, and in order to take in a proper proportion of the pulp from this part of the bale we recommend that the first bale sampled be bored in the corner at such a point that the edge of the disc shall be approximately 1 inch from the edges of the sheet. The second cut should then be made on the diagonal of the bale, half-way between the first and the centre, the third one at the centre, and so on, the fifth being in the opposite corner, located in a similar manner to the first.

"In the case of pulp shipped in rolls, the effect of drying from the surface is similar to that in baled pulp. The amount of drying taking place from the ends of the rolls, however, may frequently be considerably greater than the drying from the edges with baled pulp, on account of the fact that much of the rolled pulp is not rolled tightly enough to prevent access of the air from the ends towards the middle. It is also out of the question to adopt a method for rolled pulp which will correspond to a quarter sheet method. Obviously, therefore, any method for sampling rolled pulp to be practical must provide for taking the sample without opening up the roll, and, consequently, a method of cutting in from the surface had to be adopted. The disc method, similar to that just described for sampling baled pulp, seems to be the best adapted for sampling from rolls, and by locating successive cuts in such a way that in taking five samples the full length of a roll will be included a fair sample may be secured.

"For sampling pulp such as wet sulphite, which is shipped in laps, the method to be used is much more readily determined upon, as in this case it can easily be arranged so that in successive samples the proper proportion from various parts of the sheet as made upon the wet machine may be taken.

"The handling of pulp samples after they have been taken is almost as important as the methods by which they are selected. In the cases of many mills, pulp samples are exposed to the drying action of the atmosphere for a considerable time before being weighed, and appreciable errors are often introduced in this way. For instance, in some mills the samples are collected by the man doing the sampling and carried by him in his hand or pocket to the office or place where the testing is done. During the time the pulp is thus exposed it may lose almost 1, or even 2 and 3 per cent. in the case of wet pulp. Numerous tests have shown that for wet pulp only a very brief exposure is necessary in order to bring about such changes in moisture content. The use of air tight containers in which the sample is placed immediately upon being taken has been adopted in many mills, and this, of course, ensures against such changes.

VI. Some experimental Results.

The Sampling of Rolls.—The sampling and testing of sulphite or mechanical pulp packed in the form of rolls is a case which deserves attention. The same principles which govern the sampling of moist pulp packed in square bales may be applied with equal accuracy to roll pulp.

The principle commonly applied in the case of bales of mechanical or sulphite pulp requires that the samples cut shall be strictly proportional to the volume of pulp they represent. That is to say if four pieces of equal size are cut from four portions of the bale they must represent equal volumes; for example, if the bale is divided into four equal sections each containing two cubic feet, then each sample should contain equal volumes, and if one of them contains two cubic inches, the other pieces also must contain two cubic inches each.

This simple method can be used readily in the case of moist roll pulp, and this is easily explained by example:—

Let Fig. VII. represent the end view of a roll of moist pulp having a diameter of 24 inches with a hole in the centre of about 3 inches diameter, which hole is due to the use of a shell required for the winding up of the pulp into the form of a roll. If the area occupied by the pulp is divided into five equal sections as marked in the diagram by the letters A, B, C, D, E, then the actual volume of pulp within those sections, and running down the whole length of the roll, would be the same in each case.

The area of a circle 24 inches in diameter is 452·39 square inches, while the area of a circle 3 inches in diameter is 7·07 square inches. The difference between these two figures represents the area of the end section containing pulp. This amounts to 445·32 square inches.

In this instance it is supposed that five samples are to be cut from the bale, which number involves a division of the area into five parts, viz., $445{\cdot}32 \div 5 = 89{\cdot}06$ square inches. The

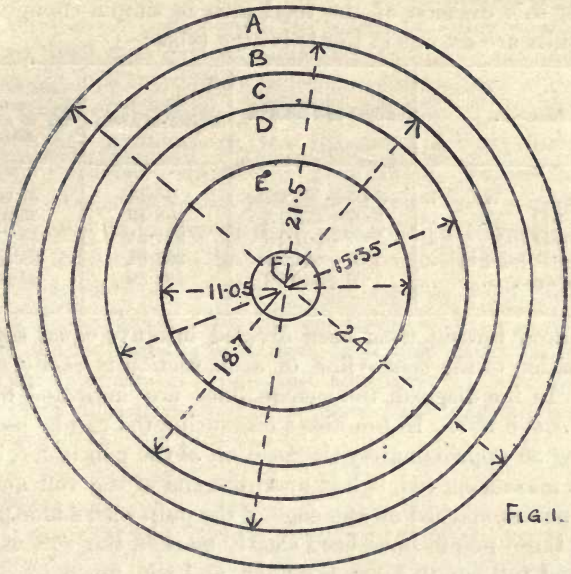


FIG. 1.

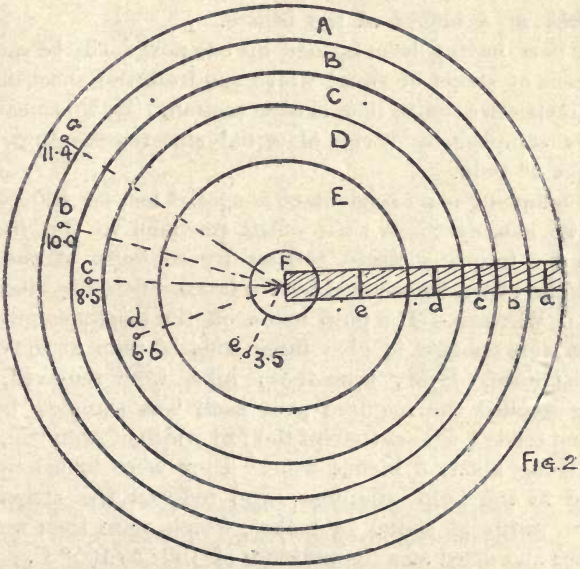


FIG. 2

Fig. VII.—Diagram illustrating Method of Sampling Rolls.

calculation of the diameters of the concentric circles necessary to effect this division of the total area is simple enough, and the results are set out in the following table:—

Sections.	Areas of Sections.	Sum respective Areas.	Diameter of circle corresponding to sum of Areas.
F+E	7·07+ 89·06	96·13	11·05″
F+E+D	7·07+178·12	185·19	15·35″
F+E+D+C ...	7·07+267·18	274·25	18·70″
F+E+D+C+B ...	7·07+356·24	363·31	21·50″
Whole area	7·07+445·32	452·39	24·00″

The area having thus been divided into five equal sections the position of the centre line of each section is easily calculated. In the diagram the centre lines are indicated by the letters *a*, *b*, *c*, *d*, *e*. In practice a measuring rod can be used for marking off approximately the position of the points *a*, *b*, *c*, *d*, *e*.

This measuring rod is laid upon the end of the roll and the centre points marked on the edge of the pulp with a blue pencil. When these points have been clearly marked the roll of pulp is placed full length upon the floor and slit down to within 3 inches or 4 inches of the centre.

The bale having been opened up can now easily be sampled by means of strips of equal width cut from the sheet nearest to the respective centre lines of each section. By this means the pulp is sampled by strips of equal size representing equal volumes of pulp.

The following is an account of a special test on 400 rolls of sulphite, manufactured six months previous to the time at which the test was made, the air-dry contents of the rolls having then been determined by the process here described.

Mill Method.—The pulp made on the machines produced a sheet wide enough to give three rolls of pulp at the end of the machines. Every time these rolls were removed, after having reached the required size, each was sampled by the machine tender, who cut strips the full width of each roll, these strips being about 3 inches wide. They were folded up and handed to the pulp examiner, who reduced the strips to a uniform width of about 1½ inches, which were then weighed together and dried at a temperature of 100° to 105° C. Since every bale was thus sampled and tested for moisture it follows

that this method is the most accurate and satisfactory. The pulp examiner is fully occupied with this work and nothing else, so that it is evident that the testing of the pulp was carried out in a thoroughly conscientious manner.

The whole of the bales having been numbered in consecutive order during manufacture, the selection of bales for testing was easily effected, as it was possible to insure that the numbers were equally distributed over the whole consignment.

As a matter of interest it may be noted that the gross weight of the 20 bales selected, at the time of manufacture was 2,648 lbs,, and at the time of the special test this weight had been reduced to 2,473 lbs. The selected bales were then examined by the method already described, each bale being tested separately for the purpose of adequate comparison. The following table gives the gross weight of each bale together with the percentage of air-dry pulp :—

Roll No.	Mill Records.		Special Test.	
	Per cent. Air-dry Pulp.	Gross Weight. Lbs.	Gross Weight. Lbs.	Air-dry per cent. Pulp.
1	90·19	123	119	94·09
2	88·65	140	137	89·25
3	92·89	151	157	93·09
4	81·83	135	121	86·53
5	89·06	136	130	92·89
6	75·75	112	96	84·60
7	89·58	132	132	89·87
8	63·44	164	134	76·61
9	85·82	121	112	93·81
10	87·64	117	112	89·20
11	84·07	120	105	91·08
12	76·91	109	104	89·68
13	86·53	131	125	85·06
14	86·53	145	134	89·43
15	94·29	138	133	90·90
16	82·04	119	115	82·90
17	79·61	130	107	90·62
18	80·01	157	145	90·56
19	83·83	145	132	90·59
20	88·86	123	123	93·02
	84·37	2,648	2,473	89·18

In comparing these figures, however, it must be noticed that the percentage of air-dry pulp under the heading "Mill Records" is the mean figure obtained by sampling the three rolls from the machine, and does not quite represent the actual

test on the selected roll. From the various tests the following comparison can be made:—

	Gross Weight of Rolls. Lbs.	Air-dry Pulp. Per cent.	Air-dry weight of the Rolls.	
			20 Selected Rolls. Lbs.	Calculated for 400 Rolls. Lbs.
Mill test on 400 rolls... ...	50,960	85·88	--	43,764
Mill test on 20 rolls... ...	2,648	84·37	2234·1	44,682
Special test on 20 rolls ...	2,473	89·18	2205·5	44,111

The special method described gives a final result which is reasonably near the mill test, and therefore the principle enunciated in the first chapter, viz., that the samples cut from the bale should bear the same proportion to one another as the volumes of pulp they represent is one that is practical and logical.

The comparison may be shown by converting the weights into tons and cwts. In that case the results are:—

	Gross Weight of Rolls.				Air-dry. Per cent.	Net Air-dry Weight of 400 Rolls.			
	Tons.	cwt.	qrs.	lbs.		Tons.	cwt.	qrs.	lbs.
Invoice ...	22	15	0	0	85·88	19	10	3	0
Special test	22	1	2	12	89·18	19	13	3	11

The consignment appears to contain a small proportion of excess pulp, as determined by the test applied.

The "Parallel Strip" Method.—This method is used in Continental countries and requires the selection of three or four sheets from the bale. Strips one inch wide are cut from each sheet midway between the edge of the sheet and the centre line. These strips are cut alternately parallel to the long side of the sheet and to the short side.

Of course such a system is a purely empirical one based upon experimental evidence probably, and cannot be criticised exactly without sufficient data. At the same time it would appear as though the method might favour the pulp maker under certain circumstances and the paper maker under others. Thus, for example with pulp, rather wet on the edges, the system might give too high a percentage of pulp, while with pulp dried out on the edges, the method would give too low a percentage.

Considered mathematically, a strip of uniform width does not give the true proportion of "outside" and "inside" pulp.

On the other hand the selection of the sheets may be effected in such a manner as to nullify any possible errors.

Recently the writer visited a paper mill in France for the purpose of making an official test on a parcel of pulp, and arranged to sample the bales by the usual wedge system and the strip method in use at the mill.

After the bales had been weighed, three sheets were selected, as representing the bale. From each sheet a wedge was cut, and also a strip one inch wide. The wedges were cut from different edges each time, and the strips were cut, two from positions parallel to the short side. These strips were in each case taken through the centre of the sheet.

Now a strip taken through the centre of a sheet takes too large a proportion of the inside pulp. Take the case of a sheet 24 by 20, having a small rectangular piece 10 by 12 marked in the centre. Then the area of the whole sheet is 480 and that of the small piece 120. The sample drawn should therefore contain *one* part by volume of the smaller area and *three* parts by volume of the remaining area. A wedge gives a sample with these relative proportions, but a strip drawn through the centre takes *equal* parts from each. This will be shown more clearly by a diagram. A strip drawn parallel to the longer side will contain a piece 1 by 12 to represent the smaller area and two pieces each 1 by 6 to represent the larger area.

The figures obtained by testing a large number of bales are shown in the accompanying table :—

TESTS FOR MOISTURE (WEDGE METHOD.)

No.	Weight of Sample Cut.		Percentages—Pulp.	
	Wet Weight grammes.	Abs. dry weight grammes.	Abs. dry Per cent.	Air-dry Per cent.
1	854·4	384·5	45·00	50·00
2	682·5	307·0	44·98	49·97
3	657·0	290·5	44·21	49·12
4	648·0	288·0	44·44	49·37
5	537·0	244·0	45·43	50·47
6	596·5	267·5	44·84	49·82
7	582·2	258·0	44·31	49·23
8	545·0	242·0	44·40	49·33
9	602·0	271·0	45·00	50·00
10	569·5	252·0	44·24	49·15
	6,274·1	2,804·5	44·68	49·64

TESTS FOR MOISTURE (STRIP METHOD.)

No.	Weight of Sample Cut.		Percentages—Pulp.	
	Wet Weight grammes.	Abs. dry weight grammes.	Abs. dry Per cent.	Air-dry Per cent.
1	2,832·0	1,271·0	44·87	49·85
2	2,864·0	1,271·0	44·37	49·30
3	2,683·0	1,192·0	44·42	49·35
4	2,865·0	1,267·0	44·22	49·13
5	2,549·5	1,153·0	45·22	50·24
6	2,688·5	1,192·0	45·33	50·36
7	2,617·5	1,155·0	44·12	49·02
8	2,729·0	1,210·0	44·33	49·25
9	2,788·7	1,249·0	44·78	49·75
10	2,866·0	1,256·0	43·82	48·69
	27,483·2	12,216·0	44·45	49·49

Each test shown represents 10 bales.

On comparing the two methods it will be noticed that in almost every case the wedge system gives a slightly higher result. On a consignment of 1,000 bales this small difference would not have any appreciable effect.

The "Official" Method.—Some years ago a joint committee of the trade associations, interested in the question of moisture in wood pulp, was appointed to consider the possibility of introducing a uniform system of sampling the bales of pulp. The paper makers and wood pulp agents of England were each represented, as well as the wood pulp and cellulose manufacturers of Norway and Sweden.

The system finally accepted as worthy of trial was one suggested by Mr. Bommen, of Viul Traesliberi, Norway, a complete description of which is given on page 21.

The writer visited Sweden in 1908 for the express purpose of investigating the value of this method, and to compare it with the wedge system as used in England. The exact method of sampling pulp adopted by the author was based on the following plan :—

The selected bale was supposed to be divided into four equal sections. The first section, however, consisted of two parts, one being at the top and the other at the bottom of the bale. Thus the bale contained five sections, h, $2h$, $2h$, $2h$, h (see Fig. I., method A, page 16). From the *centre* sheet of each

section a wedge was cut, those of $2h$, $2h$, $2h$ being equal and those of h, h being each half-sized wedges.

In practice, seeing that the top and bottom of each bale could be regarded as identical, four wedges were cut of *equal* size, from the centres of the four sections h, $2h$, $2h$, $2h$, the last h being omitted.

Twelve pulp mills were visited for the purpose of the investigation, and twenty-three tests, each consisting of six bales were carried out. In every case the six selected bales were carefully weighed and simultaneously sampled by the suggested official method, and also by the English wedge system as represented by Method A. Half the tests were applied to moist mechanical pulp, and the remainder to ordinary dry chemical pulp, the bales being drawn from stock at random.

Table No. 1 gives the result of these tests :—

Test No.	No. of Bales.	Gross Weight of Bales. (Kilos).	Percentage Air Dry Pulp.		Mechanical or Sulphite.
			Official Method.	English Method.	
1	6	761·6	103·97	104·80	S
2	6	755·4	92·93	92·46	S
3	6	1,041·0	48·80	49·80	M
4	6	1,017·2	52·45	52·02	M
5	6	997.5	52·22	52·81	M
6	6	1,042·2	43·15	42·52	M
7	6	975·9	48·33	47·47	M
8	6	1,008·5	52·67	52·13	M
9	6	764·1	100·53	100·29	S
10	6	750·2	95·80	96·12	S
11	6	1,218·0	50·51	51·35	M
12	6	1,216·0	52·22	53·39	M
13	6	763·0	98·52	98·50	S
14	6	780·0	99·00	99·75	S
15	6	602·45	102·65	102·09	S
16	6	596·5	52·28	51·80	M
17	6	607·7	46·28	46·73	M
18	6	625·7	98·65	98·31	S
19	6	628·1	98·54	97·92	S
20	6	762·8	102·20	102·87	S
21	6	616·25	49·22	50·05	M
22	6	868·7	97·44	97·97	S
23	6	858·7	97·88	98·29	S

If these figures are closely examined, it will be noticed that the difference in the amount of air-dry pulp as found by the two systems is half per cent. above the official method, and

sometimes half per cent. below. If it is assumed for the sake of argument that the two methods are of equal value, then the average of the two methods would give the correct result, and in this case the error of either method would only be one quarter per cent., sometimes above and sometimes below the average.

An adequate comparison of the results obtained by the two systems may be shown by assuming that in each of the 23 tests the official method applied to a certain number of bales gave exactly 100 tons of air-dry pulp.

Hence, assuming that the amount of air-dry pulp found by the official system is exactly 100 tons in each of the tests, what would be the weight of that pulp tested by the English method? The answer to this question is given in the following table :—

Test No.	Air-dry Weight of Pulp.				
	Official Method.	English Method.			
	Tons.	Tons.	cwt	qrs.	lbs.
1	100	100	15	3	0
2	100	99	10	0	0
3	100	102	0	3	0
4	100	99	4	0	0
5	100	101	2	1	0
6	100	98	11	0	0
7	100	98	4	2	0
8	100	98	19	0	0
9	100	99	15	1	0
10	100	100	6	2	0
11	100	101	12	0	0
12	100	102	5	0	0
13	100	99	19	2	0
14	100	100	15	0	0
15	100	99	10	0	0
16	100	99	19	2	0
17	100	100	19	2	0
18	100	99	13	0	0
19	100	99	7	2	0
20	100	100	13	0	0
21	100	101	14	0	0
22	100	100	11	0	0
23	100	100	8	0	0
	2,300	2,305	16	0	0
Average ...	100	100	5	0	0

The comparison reduced to this form enables one to judge of the merits of the systems. While it is obvious that in one or two cases the differences are serious, yet taking all the cases into consideration the average difference is small. The following final result is obtained :—

Method.	No. of Tests.	Air-dry Weight				Average			
		Tons.	cwt.	qrs.	lbs.	Tons.	cwt.	qrs.	lbs.
Official... ..	23	2,300	0	0	0	100	0	0	0
English ...	23	2,305	16	0	0	100	5	0	0

This is a difference of $\frac{1}{4}$ per cent. as shown in the earlier part of this report, and is a negligible quantity.

No doubt the value of this test would have been considerably increased if the whole of these bales had been repacked, sent to England and tested again after having been in stock for a few weeks.

Control Methods.—A careful comparison of various methods of testing pulp cannot lead to any definite conclusion as to the merits of the respective systems, unless there is some effective means of control or some standard by which the accuracy of the methods can be determined. Two methods differing widely in principle may give the same results, or on the other hand may give figures showing considerable variation. In such a case nothing is proved unless the deviations occur with constant regularity, one method always showing lower results than the other. When this occurs it is clear that in one of them there is a constant source of error, the reason for which further investigation should discover.

The introduction, if possible, of some third system of testing, differing materially from the two which have been compared, becomes a necessity when it is required to ascertain the value of other methods.

The mere fact that a test made along certain lines always gives the same result is no argument that the test is beyond reproach. Persons accustomed to the routine testing of wood pulp, particularly those in charge of the pulp testing either at the pulp manufactory or at the paper mill, adopt some particular system of sampling, and adhere to this for years and regard the constant use of one particular system as evidence

of its accuracy. The merits of any particular system can only be rightly judged by those who, having no bias for any particular system, are willing and able to compare various methods and judge of their merits on experimental evidence.

The question of a control method is obviously one of great importance. It has been suggested that occasionally a whole bale should be dried out completely at a temperature of 100° C, but the errors arising from such a course of procedure are almost too obvious to need any explanation. If the bales were uniform in gross weight and in the percentage of moisture, such a method of control would be of great value, but uniformity of this description is generally conspicuous by its absence.

Similarly the comparison of various methods cannot accurately and adequately be found in tests made on a single bale. Experimental errors are invariably larger when the test is made under the abnormal conditions due to such a test. The law of averages, in which experimental errors made with one bale are counterbalanced by experimental errors of an opposite character, occurring with another bale, does not come into operation effectively, if at all, when the test is confined to a single bale.

Any control method which is devised for the purpose of checking the results obtained by two or more methods must give fairly consistent results, and should preferably have radical differences in operation. The importance of this subject was brought under the notice of the writer in the examination of some mechanical pulp. It had been arranged that a large number of bales should be sampled by the English wedge system, the precise method adopted being that described as method A (see page 16).

The particular bales examined were found to contain very thick folded laps or sheets of pulp, 18 in number, and the following system was suggested as likely to produce a satisfactory "control" method.

Description of Control Method.

As each bale contained on an average 18 sheets of pulp, it was decided to weigh carefully 18 bales and to use 18 bales for each test. These bales were placed in a row side by side. Every bale was sampled by method A, the whole of the wedges cut from the 18 bales being put together in a tin provided for

the purpose. Simultaneously the same bales were tested by the "control" method. That is, the top sheet of the first bale was put aside, the second sheet of the second bale was put aside also, the third sheet from the third bale, and the fourth sheet from the fourth bale, until 18 sheets drawn in this manner from the 18 bales were put aside, producing what may be finally termed a "composite" or "control" bale, the top sheet of which was the top sheet of the first bale, and the bottom sheet of which was the bottom sheet of the 18th bale. The composite bale was then sampled as follows:—A wedge was cut from the short side of the top sheet through the *whole thickness* of the sheet or lap itself. (This differs from the ordinary method of cutting the wedge, in which the sample is simply cut from the top fold of the sheet and is not cut through the whole thickness.) From the second sheet a similar wedge was cut through the long side of the sheet, and from the third sheet another wedge was cut through the short side, and so on for all the 18 sheets of the composite bale. These were alternated with wedges cut from the corners to the centre. In effect, the sample thus cut was a solid wedge taken through the composite bale from top to bottom.

Naturally the amount of sample obtained in the latter case was far greater than the amount obtained by the ordinary wedge system, the quantity being roughly about eight times as much. The method seemed to have much to recommend it as being radically different in principle and yet based on reasonable assumptions.

The control method when applied to a large number of bales gave results of a most valuable character. The test was applied under very severe conditions, since the material sampled was a large consignment containing pulp which had been manufactured within two months of its delivery to the mill, and also a considerable quantity which had become very dry owing to long storage and exposure to air. This is sufficiently obvious from an examination of the gross weights of the bales.

Experiment No. 1.

For this test 468 bales were selected. The bales were weighed six at a time on special scales, and each 36 bales tested separately. The experiment, therefore, was a thoroughly exhaustive one, containing 13 separate tests of 36 bales each.

The bales were sampled by the two methods described and the results are given in Tables I. and II.

TABLE I.

Tests for Moisture, by "Ordinary Wedge" method, showing wet weight of sample cut, &c.

No. of Test.	Bales Weighed.	Sample Wet Weight.	Sample abs. Dry Weight.	Abs. Dry Pulp.	Air-Dry Pulp.
		grms.	grms.	per cent.	per cent.
1	36	1,910	960	50·26	55·85
2	36	1,940	982	50·61	56·23
3	36	1,580	781	49·43	54·92
4	36	1,900	931	49·00	54·44
5	36	1,450	748	51·60	57·33
6	36	1,482	789	53·34	59·26
7	36	1,910	990	51·64	57·38
8	36	1,380	725	52·53	58·37
9	36	1,450	742	51·20	56·90
10	36	1,400	735	52·50	58·33
11	36	1,600	832	52·00	57·78
12	36	1,100	570	51·89	57·66
13	36	1,500	765	51·00	56·67
	468	20,602		51·30	57·00

TABLE II.

Tests for Moisture, by "Control" method, showing wet weight of sample cut, &c.

No. of Test.	Bales Weighed.	Sample Wet Weight.	Sample abs. Dry Weight.	Abs. Dry Pulp.	Air-Dry Pulp.
		grms.	grms.	per cent.	per cent.
1	36	5,820	2,910	50·00	55·56
2	36	4,800	2,386	49·71	55·23
3	36	5,500	2,724	49·52	55·02
4	36	5,000	2,428	48·56	53·96
5	36	4,600	2,346	51·00	56·67
6	36	4,600	2,456	53·39	59·32
7	36	3,860	2,070	53·62	59·58
8	36	5,580	2,964	53·12	59·02
9	36	5,300	2,708	51·09	56·76
10	36	4,340	2,290	52·76	58·62
11	36	5,000	2,620	52·40	58·22
12	36	4,260	2,260	53·05	58·94
13	36	3,600	1,800	50·00	55·56
	468	62,260		51·40	57·11

These results are remarkable, and the final result appears to indicate that the Control method suggested is an extremely valuable one. Applying these percentages to the actual gross weights found the air-dry weight was as follows:—

TABLE III.

Test No.	Bales Tested.	Gross Weight, each 36 bales.			Air-dry Pulp.		Air-dry Weight One Bale.	
					Ordinary Method.	Control Method.	Ordinary Method.	Control Method.
		Cwt.	qr.	lbs.	Per cent.	Per cent.	Lbs.	Lbs.
1	36	124	2	10	55·85	55·56	216·48	215·35
2	36	125	0	1	56·23	55·23	218·69	214·80
3	36	125	2	15	54·92	55·02	214·67	215·24
4	36	127	0	26	54·44	53·96	215·49	213·59
5	36	121	3	17	57·33	56·67	217·42	214·92
6	36	120	2	6	59·26	59·32	222·26	222·48
7	36	121	0	14	57·38	59·58	216·22	224·51
8	36	117	2	15	58·37	59·02	213·60	216·00
9	36	123	1	26	56·90	56·76	218·60	218·05
10	36	123	2	16	58.33	58·62	224·36	225·49
11	36	120	2	2	57·78	58·22	216·65	218·21
12	36	118	0	17	57·66	58·54	211·98	216·66
13	36	119	1	15	56·67	55·56	210·50	206·35
	468	1,588	3	12	57·00	57·11	216·69	217·05

Of course considerable variations and differences will be noticed in these comparative tests. For example, in test No. 7 the two methods vary by 8 lbs. per bale. This is an extreme case and does not minimise the value of the Control. The bales themselves evidently vary to an extraordinary degree in the amount of air-dry pulp. Thus, comparing test No. 13, which by the ordinary method gives 210·5 lbs. of dry pulp per bale, with test No. 10, giving 224·36 lbs. per bale, we have a difference of 14 lbs. per bale. This is a large difference having regard to the fact that no less than 36 bales were taken for each test. If such large differences occur between individual bales found by such a method it is not surprising that two methods of testing should also show variations in the final results.

The value of this special Control method was examined a second time some few months later, on another delivery of pulp. The investigation was made in precisely the same

manner, and the results were confirmed. The percentage of air-dry pulp determined by the ordinary method of testing was 59·22 per cent., while the percentage found with the Control method gave 59·24 per cent.

One hundred and eighty bales were examined in this way, so that the test was clearly on a sufficiently large scale for the purpose. In this second test also considerable variations were found in individual tests, as might have been expected.

VII. The Measurement of "Probable Errors."

THE importance and interest attaching to this subject will be apparent enough after a study of the various matters discussed.

When a large delivery is being sampled, involving the actual drawing of pieces from a considerable number of bales, it is sometimes better to divide the bales into three or four lots in order to secure several duplicate tests than to place all the strips or pieces cut out into one vessel, and then make one single test.

By such a comparison of duplicate tests it is possible to measure the accuracy of the result and to gain some idea as to the chances of a second series of duplicate tests giving the same percentage of air-dry pulp under varying conditions.

When a single test is made on a large number of bales no evidence is forthcoming in it to show to what extent the test may be relied on, or the limits of error which may be peculiar to it, since only one result is obtained from which it is impossible to draw any conclusions save the amount of dry pulp in the parcel. But when that same number of bales is divided into equal lots, each being independently tested, the comparison of the figures obtained does give the required information.

Suppose, for instance, a parcel of wood pulp is consigned and invoiced 2,500 bales mechanical pulp, 250 tons, 50 per cent. air-dry, and that 2 per cent. of the parcel is to be tested.

This gives 50 bales to be sampled. Now, if these bales are opened, and the pieces which are drawn placed together and tested in one lot, the only information gained is the final air-dry percentage.

If, on the other hand, the 50 bales are divided into five lots of 10 bales each, and five smaller independent tests made, the error on the average result can be calculated, and obviously this would be a material advantage, giving at once a very close idea as to the chances of the result of a second test on another 50 bales.

To avoid complicated calculations, it may be assumed that each lot of 10 bales has the same gross weight, and that

Result of Test No. 1, made on 50 bales, is 50·8 per cent.

Result of Test No. 2, made in 5 lots, is 50·8 per cent.

1st Test.	2nd Test.
	(1) 51·2
One	(2) 49·8
Sample	(3) 50·6
only.	(4) 51·8
	(5) 50·6
Mean - 50·8	Mean - 50·8

Average Errors.—What is the average error on any one of the five tests and the average error on the mean result?

It would appear at first sight as though no satisfactory conclusions could be arrived at when a discrepancy of 2 per cent. occurs between two of the tests. This would not be a fair argument, because under the conditions of Test No. 1, the difference would not show itself, and this method is the one generally adopted in actual practice. Then, again, this way of looking at the figures is scarcely correct. It is true that 2 per cent is the greatest *difference* between two individual tests, but it does not represent the greatest *error* in any one test.

It is necessary to discriminate between the two words "difference and "error," or, more accurately speaking, between the meaning of the phrases "maximum difference" and "maximum error."

The several deviations of each individual figure in the second test from the mean result are given below in Col. 11, where the sign of plus or minus is prefixed to indicate that the test is above or below the mean. The minimum error 0·2 per cent. occurs twice in this particular series, being obtained as before from the difference between the mean and the lowest test, $50 \cdot 8 - 50 \cdot 6 = 0 \cdot 2$ per cent.

The *maximum error* is $51 \cdot 8 - 50 \cdot 8 = 1 \cdot 00$, while the *maximum difference* is $51 \cdot 8 - 49 \cdot 8 = 2 \cdot 00$.

	Col. I.	Col. II.
	51·2	+0·4
	49·8	−1·0
	50·6	−0·2
	51·8	+1·0
	50·6	−0·2
Mean ...	50·8	2·8

A comparison of the figures obtained in this way by duplicate tests reduces them to a condition in which large differences have just their proper significance.

The statements given in the table of figures above can be utilised still further. Just as it is possible to calculate the average or mean result of a number of observations as to the percentage of moisture, so it is equally possible to determine the average or mean of a number of errors. In the example quoted the maximum and minimum errors are 1·0 per cent. and 0·2 per cent. respectively.

What is the average error on any test, and the probable error on the mean result?

The answer is worked out in the following manner:—Arrange all the observations made, in a vertical column, with the mean result last, as shown in Column I. Opposite each number write the difference between it and the mean, prefixing the signs plus or minus, as the case may be, giving Column II. Add all the differences together, ignoring the signs plus or minus, placing the addition below the column. Divide this sum by the number of observations, and the figure obtained represents the average error on the various tests in the series.

$$\text{Error} = 2 \cdot 8 \div 5 = 0 \cdot 56 \text{ per cent.}$$

Whenever a number of observations are obtained, each of which is supposed to give approximately the same result, there is a certain error liable to occur in every one, and also on the mean result. The latter is, of course, nearer the truth than any of the individual tests, but at the same time it is incorrect to some extent by an amount which will naturally be smaller than the figure representing the average error in the series.

It is necessary to note this, because it may be argued that there is an actual deviation of 1·0 per cent. between some of the observations occurring in the example quoted and the mean result, a difference which is repeated in this series twice.

This calculation shows that it is possible to determine the value of the mean test and the extent to which it can be relied upon. It would be interesting in this connection to compare two series, one having only small variations in a number of consecutive observations, and the second somewhat greater differences.

To render the comparison more obvious, it may be supposed that the mean result in both is the same. Thus :—

Series I.		Series II.	
Test.	Error.	Test.	Error.
51·2	+ 0·4	50·0	− 0.8
49·8	− 1·0	48·5	− 2·3
50·6	− 0·2	50·2	− 0·6
51·8	+ 1·0	52·3	+ 1·5
50·6	− 0·2	53·0	+ 2·2
Mean 50·8	2·8	Mean 50·8	7·4

It is only necessary to note the larger differences between individual tests found in the second series, to decide that the condition of the pulp is not so satisfactory as in the first. The calculation of the average error in the manner suggested shows the relative value of each series. In the first, the average error is $2{\cdot}8 \div 5 = 0{\cdot}56$ per cent., while in the second the error is much larger, being $7.4 \div 5 = 1{\cdot}5$ per cent. Now with a moist pulp invoiced at 50 per cent., delivered in good condition, such extreme differences as 53·0 and 48·5 would seldom occur, especially under the present assumption of each test giving the same gross weight. Hence in all probability, a repetition of Series II. would give further percentages lying between those two limits, and therefore lower the average error. To illustrate this we may combine Series I. and II.

The average percentage of pulp would still be 50·8, and the error $(7{\cdot}4 + 2{\cdot}8) \div 10 = 1{\cdot}02$ per cent., being about 0·5 per cent. less than the error in Series II taken by itself. Thus the larger the number of tests, the more reliable is the

mean result, which argument carried out to its logical conclusion means that the most correct test is one which includes every bale, a proceeding which is unnecessary.

Just as the mean result of a number of observations is perhaps more correct than any of the observations themselves, it follows that the probable error on the mean must be less than the average error amongst the individual tests. Clearly, also, a test which has only a small probable error is more reliable than one showing a large probable error.

Probable Error on the Mean Result.—To determine the probable error on the mean divide the average error by the square root of the number of tests. This is an approximate rule which is sufficiently accurate for figures of this kind where the differences between readings are in reality beyond the control of the observer.

Let average error ... . = E
and number of tests ... ... = n
Probable error on mean result ... ... = $E \div \sqrt{n}$.

From this mathematical rule the figures for Series I. and II. are—

	Series I.	Series II.
Average error ...	0·56	1·50
Number of tests ...	5	5
$\sqrt{n}$	2·24	2·24
Probable error ...	0·25	0·70

These calculations serve to confirm the observation which comes of practical experience, that the smaller the actual differences between consecutive tests, the more correct is the mean result.

Here in one series where two tests differ by 2 per cent., the probable error on the mean is 0·25, while in another, where the tests differ by 4·5 per cent. in two instances, the probable inaccuracy of the mean is 0·70 per cent.

Applying these arguments to the weight of dry pulp found in a consignment of wood pulp the effect of the probable error can be shown in a manner which serves to emphasize its usefulness, the error being shown in terms of actual weight, The example assumed in connection with the tests given in Series I.

stated that the delivery was to consist of 2,500 bales moist pulp weighing 250 tons gross at 50 per cent. moisture.

With the mean result obtained on testing, the air-dry weight of this consignment works out thus, supposing that the gross amount received was within a cwt. or so of the invoice weight, an assumption which will save confusion of figures as before :—

250 tons at 50 · 8 per cent. dry pulp = 127 tons air-dry.

There is nothing to show whether the probable error which has been calculated is a negative or a positive quality, that is, if the calculated correct percentage should be 50 · 6 or 51 · 0. If it is the former, then

250 tons at 50 · 6 per cent. dry pulp = 126 · 4 tons,

and, if the error is a positive one, then

250 tons at 51 · 0 per cent. dry pulp = 127 · 6 tons.

In either case, the probable error is evidently only about 12 cwt. either way, a quantity which buyer and seller would mutually agree to neglect in such a large weight of pulp.

When a consignment of pulp is tested six times, ten bales each time being carefully weighed, opened and sampled, and the result of each such test used for ascertaining the nett air-dry weight six times over, then these weights can be compared and the probable error determined.

The following shows a typical example, the first column giving the air-dry weight, as found by repeated tests, together with the mean result, and column two the deviations of each test from the mean, as in previous cases. Gross weights of wet bales and the percentage of air-dry pulp found by experiment have been omitted, as they are not required for this illustration.

Invoice 250 tons moist pulp 50 per cent. air-dry 2,500 bales :—

	Col. I. Giving nett air-dry weight of 2,500 bales six times.					Col. II. Errors.				
		Tons.	cwt.	qrs.	lbs.		Tons.	cwt.	qrs.	lbs.
1	...	127	14	0	0	+	1	4	0	0
2	...	128	10	0	0	+	2	0	0	0
3	...	126	5	0	0	−	0	5	0	0
4	...	126	15	0	0	+	0	5	0	0
5	...	124	0	0	0	−	2	10	0	0
6	...	125	16	0	0	−	0	14	0	0
Mean		126	10	0	0		1	3	0	0

The average error in this series of tests is about 23 cwt., which at first sight may seem a rather large quantity, but, as one test is only on ten bales, there is no chance of this error making itself felt in practical working as, according to mutual agreement, it would be necessary to test 50 bales at least. The probable error on the mean result is the true criterion of the value of the figures obtained by sampling 50 bales, but this can only be ascertained by making five, six, or more smaller tests till the aggregate number has been dealt with. The probable error on the final mean test is readily calculated with the formula given, viz., $E \div \sqrt{n}$. In this case

$$E = 23 \text{ cwt.} \quad n = 6.$$

$$\sqrt{n} = 2{\cdot}44.$$

$$\text{Probable error} = 23 \div 2{\cdot}45.$$

$$= 9{\cdot}5.$$

So that the mean test 126½ tons is probably correct to the extent of 9½ cwt. The buyer of this parcel might safely assume that in settling the account he either receives 10 cwt. of pulp over the test figure, or pays for 10 cwt. more than he actually received according to the test. In neither case could there be much cause for complaint.

It also follows that the calculation of average and probable error cannot be made without the preliminary comparison of the air-dry weight by a series of consecutive tests made in duplicate. It is quite true that even if the gross weight of a number of identically similar bales is altered by some accident, such as undue exposure to dry air, or, on the other hand, by water finding its way to the sheets, it is possible to get a fairly reliable test, at least theoretically. But in practice the sampling becomes a difficult task, as the altered conditions of the bales are not uniformly distributed throughout, and hence it is difficult to draw a representative sample.

Suppose a bale, the gross weight of which is exactly 2 cwt., and testing 50 per cent., is exposed to the air until it loses 9 lbs. in weight, what should it test then, as to percentage? Or imagine that same bale is wetted in some way and weighs 10 lbs. over the 2 cwt. The quantity of air-dry pulp is unaltered, and that amount is 112 lbs.

In the first instance, then, the conditions of the bale are—

224 lbs. at 50 per cent. = 112 lbs.

In the second case the gross weight is decreased, and the bale then shows a result as follows :—

215 lbs. at 52 per cent. = 112 lbs.,

while in the third the increase of weight due to water gives—

234 lbs. at 48 per cent. = 112 lbs.

NOTE :—The substance of the above chapter first appeared in the journal "Paper and Pulp," now no longer published.

VIII. Apparatus for Testing Pulp.

THE kind of apparatus necessary for testing the many varieties of wood pulp used in paper making will depend to some extent on the amount of pulp drawn as a sample to represent the consignment. In a few cases the sample may weigh 25 to 30 lbs., but as a general rule the total amount is far less. The appliances may therefore be considered under three heads.

For Testing Large Samples.—The most convenient apparatus, and one which is universally employed, is so constructed as to combine a drying oven with a balance, since by this means the sample of pulp can be weighed at any moment while it is being dried without the necessity of its removal from the oven.

The largest ovens of this type are to be found at the Manchester Chamber of Commerce Testing House, capable of taking about 100 lbs. of moist mechanical pulp. These ovens are tall cylindrical vessels fitted with a steam jacket and special arrangements for the efficient circulation of heated air. The scales are attached to the side of the apparatus in such a manner that the pulp when placed in a convenient cage or receptacle and suspended to one arm of the scales, hangs in the oven and can be dried. The other arm carries a scale pan with the weights. The heat is obtained by the use of high pressure steam supplied from some existing boiler, or from a gas burner placed below the oven. The details of construction can be seen from the accompanying drawing.

A less expensive apparatus capable of taking samples of about 20 lbs. in weight is Wright's wood pulp drying oven. This appliance consists of a cylindrical vessel surrounded with an air casing, heated by means of gas, the temperature being regulated with a thermometer in the usual way. The wet pulp is weighed in the cage attached to the arm of the scales fitted

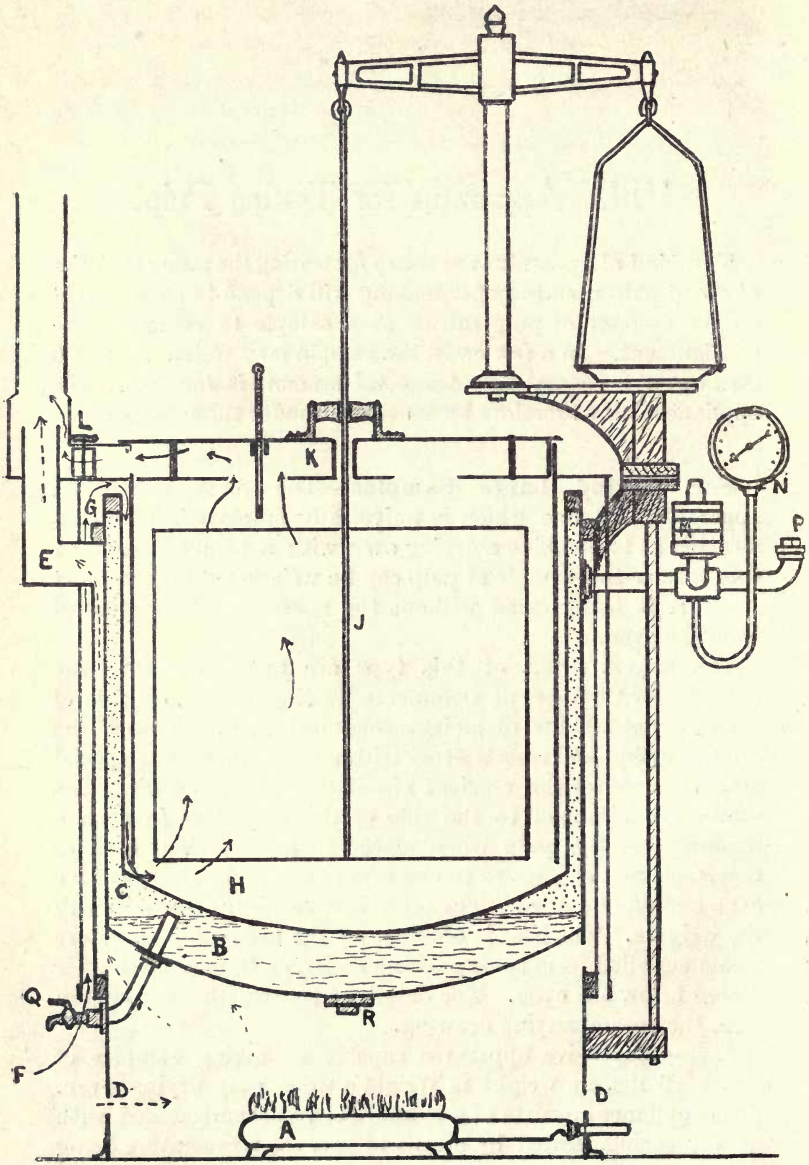


Fig. VIII. Large Drying Oven.

to the side of the oven, and being suspended to this arm while it is heated, can be weighed at any time during the drying operation. (Fig. IX.)

Facilities are also afforded whereby two or four samples can be dried out and tested at once, thus saving time and expense. This is effected by vertical divisions fitted to the cage, which is thus utilised for carrying a number of independent samples.

Schopper of Leipzig has made some fine ovens for drying pulp, capable of taking large samples. They are similar in construction and principle to those described. The most recent form of large oven is shown in Fig. X. which is interesting on account of the fact that heat is obtained by electricity.

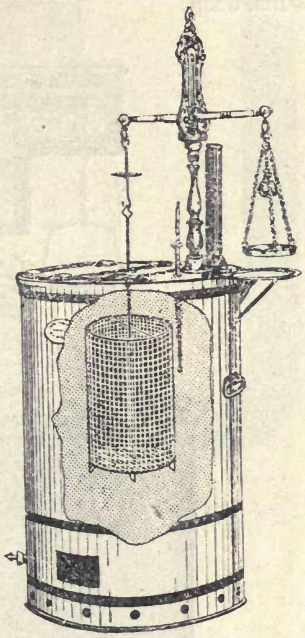


Fig. IX.
Pulp Drying Oven (Gas).

For Medium Sized Samples.—In many pulp and paper mills the drying ovens now used are of the type already described, being constructed of ordinary sheet iron, heated by steam pipes, and thus easily maintained at an even temperature from one week's end to the other without attention.

An automatic weighing and drying oven is probably the most suitable form of apparatus, in which the sample can be quickly dried, owing to the special formation of the cages holding the pulp, allowing adequate exposure to the heated air. The oven shown in Fig. XI. is capable of taking one sample, but large appliances fitted for drying out three or more samples simultaneously can be obtained. The pulp in this case is weighed while it is in the oven by means of the balance attached.

The common hot water oven can also be modified and utilised as a steam oven. The cages for the pulp should then

be made of convenient shape and size. Thus with an oven 12 ins. wide and 12 ins. from back to front the cage can be made rectangular, measuring $5\frac{3}{4}$ ins, $\times$ 12 ins. and about 3 ins. deep.

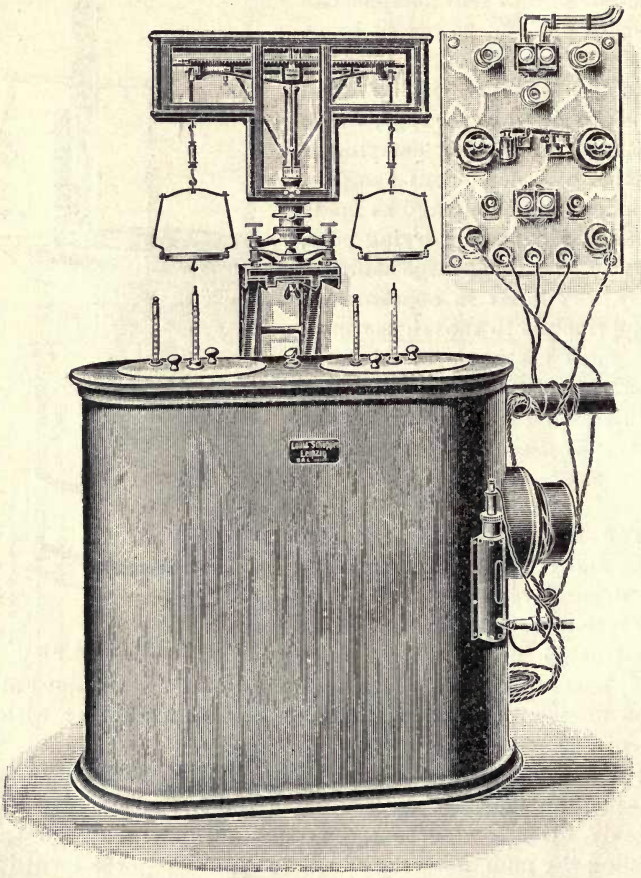


Fig. X. Drying Oven heated electrically.

If these cages are carefully made from coarse wire gauze, with corners suitably protected and covered, they can be adjusted so as to be of exactly equal weight.

In this case an independent balance will be required. A Beranger balance, Fig. XIII. may be used for samples of

300 grammes and upwards, or the more sensitive beam scales shown in Fig. XIV.

Dr. Winkler of Leipzig has constructed an oven capable of holding six or more such cages, which can be treated by gas, steam or spirit, careful provision being made for the automatic control of temperature. In a pamphlet dealing with the subject of wood pulp testing, Dr. Winkler gives the interesting statement that to maintain a temperature of 100°C. for one hour, the quantity of methylated spirit required is about 100 cc.

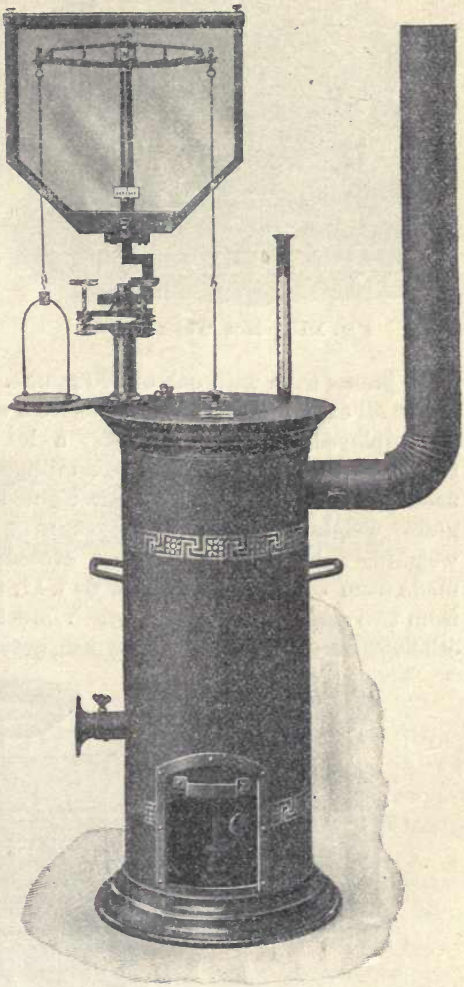


Fig. XI. Drying Oven, with Balance attached.

For testing small samples. — The examination of small quantities of pulp in experimental work requires the use of delicate and special appliances in order to minimise and avoid errors which would otherwise occur. This is easily exemplified by considering the conditions under which hot dry pulp is weighed. Thus if a wire cage containing 300 grams of hot pulp is weighed on an ordinary balance, the amount of moisture absorbed during the process is very slight, and hardly affects the reading.

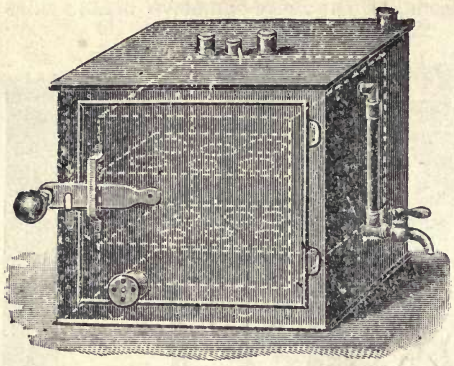


Fig. XII. Hot Water Oven.

But if the sample weighs only 30 grams it must be weighed on a more delicate balance, and since the process of weighing takes longer the absorption of moisture is greater. Other errors are also introduced, and it is obvious that a difference of 0·25 grams. is more serious with a weight of 30 grams than with one of 300 grams.

For all experimental work therefore a sensitive balance must be employed, capable of taking a load of 100 grams and turning with an addition of one milligram. The receptacles used for the pulp must be air tight and for this purpose glass weighing tubes or bottles may be employed. The weighing tubes for samples not exceeding 10 grams can be made from ordinary test tubes 6" × 1", the rims being cut off from two such tubes, one of which must fit closely inside the other.

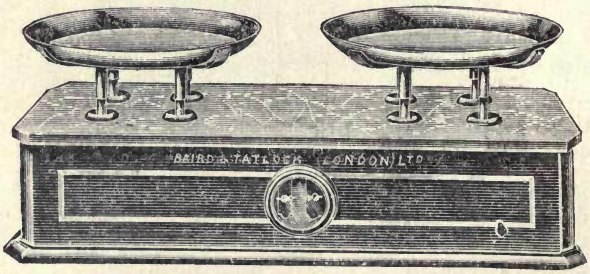


Fig. XIII. Beranger Balance.

A desiccator will also be needed in which the tubes or bottles containing the hot dry pulp can be cooled before weighing, There are many forms of this apparatus available, one of the simplest being shown in Fig. XVII.

If the pulp is to be dried at the usual temperature of 98–100 C. the ordinary hot water oven may be used, but in

special cases an oven capable of giving higher temperatures is necessary. Small copper ovens fitted with automatic gas regulators can be obtained in which the degree of heat is adjusted as required. An excellent device of this kind is Lothair Meyer's oven (Fig. XIX.), but other types are available.

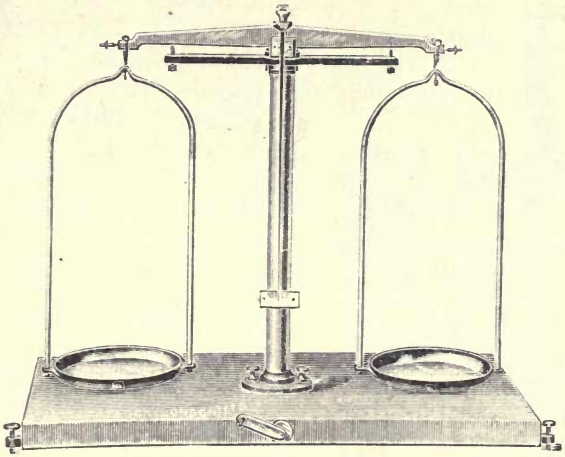


Fig. XIV. Sensitive Beam Scales.

Accessories for sampling pulp at the mill or docks.—The appliances required for sampling pulp will be determined mainly by the facilities offered at the place where the pulp s examined.

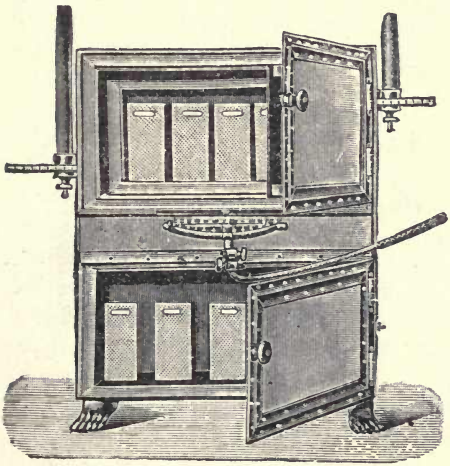


Fig. XV. Winkler's Drying Oven.

Receptacles for the Pulp—The most convenient vessel is the ordinary lever-top tin, which in good condition is practically air-tight. The use of sealing wax or paraffin wax can be resorted to, as a means of

preventing possible evaporation of moisture. These tins can be obtained in all sizes capable of taking small or large samples.

Tools for Cutting the Pulp.—When the samples consist of strips or wedges cut from the flat sheet of pulp, a short thin knife rigidly fixed in a smooth-surfaced round wooden handle is the best and simplest tool. The blade should be quite short in order that the pressure exerted when the knife is used may be sufficient to cut through the sheet of pulp without inconvenience.

Fig. XVI. Weighing Tube.

Fig. XVII. Dessicator.

An ingenious form of cutter is used in America for dry pulp consisting of an auger bit which is capable of giving circular discs 8 or 10 ins. diameter.

In France a heavy knife having two or more parallel blades is frequently employed, the strips obtained in this way being 25 millimetres broad, With a three-bladed knife two such strips are cut simultaneously. See page 26.

Drying the Samples of Pulp.—The operation of determining the absolute dry weight of the pulp is a simple matter. The wet sample, having been accurately weighed is placed in the wire cages or other receptacles and dried in the oven at a temperature of 100° C. until the weight becomes constant. The time required for drying will depend upon the quantity of material and the amount of dry air allowed to pass through the drying oven.

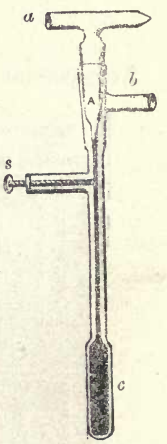


Fig. XVIII. Gas Regulator.

Samples of moist mechanical pulp can be very rapidly dried if shredded into thin layers and exposed to a plentiful current of hot air. Great care is necessary to ensure that the final weight is absolutely constant, and to this end it is advisable to expose the pulp a further period of two hours after it has become apparently constant in weight. This will ensure that no further diminution in weight takes place.

Extensive experiments have been made by Professor

Herzberg, of the Imperial Paper Testing Institute, Germany, showing that pulp can be completely dried at any temperature between 90° C. and 105° C., the operation taking longer at the lower temperature.

His report is published in several paper trade journals, and the results show that the old method of heating is quite reliable and far more rapid than the proposed method of heating only at 90° C. For the purpose of his experiments Professor Herzberg was provided with samples of bleached and unbleached sulphite and soda wood pulps and bleached straw pulps. Samples of each pulp also had purposely been imperfectly washed in order that the results might be compared with those obtained with properly washed specimens. Professor Herzberg experimented with nine different processes of drying. He compared the effect of first drying the moist pulp at a moderate summer temperature, before subjecting it to oven heat, with that of putting the moist samples straight into the drying oven. He also compared the effects of drying the pulps in currents of dry hot air and nitrogen; also of drying in vacuum. He also dried the samples at temperatures of 90° C. and 105° C. The summary of all his experiments shows that none of the above variations makes any practical difference in the results, the differences found were so small that they could be neglected as falling within the limits of unavoidable experimental error. Even with pulp heated at 120° C. it was doubtful whether the excessive temperature caused any really appreciable loss of weight owing to decomposition. There is consequently no reason for introducing any modification or complication in the usual process of drying the wood pulp at a temperature of 105° C.

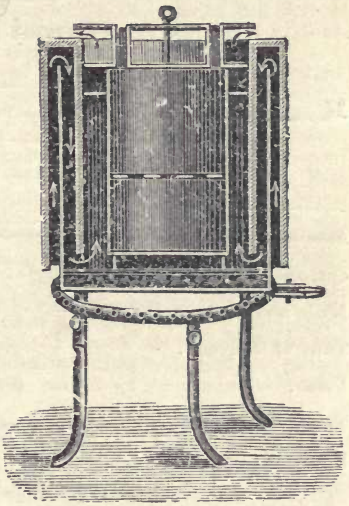


Fig. XIX.
Lothair Meyer's Oven.

IX. Wood Pulp Contract Notes of Various Countries.

United Kingdom.

*M*_____

*We have this day*_____

Quantity and Description of Goods :—

Mode and Place of Delivery :—

Time of Delivery :—

Price :— (Cash before delivery if required.)

Terms of Payment :—

Remarks :—

Subject to the Conditions printed on the back hereof.

_____ 191____

CONDITIONS.

(1.) **Packing and Weight.**—The pulp to be packed in bales of declared uniform weight, or a specification to be given stating the weight and number of each bale. The price is per ton of 2,240 lbs. (1,015 kilos.) gross for net. By air-dry weight is understood 90 parts of absolutely dry pulp and 10 parts of water.

(2.) **Quantity.**—Should the buyer question the quantity of pulp invoiced, the dispute shall be determined by an agreed analyst. In the event of a dispute as to the appointment of an analyst the buyer shall submit to the seller three names from a list of analysts approved by the British and Scandinavian Pulp Associations and the Paper Makers' Association, one of whom must be selected.

The analyst shall test the pulp within 10 days of the buyer's claim being made, either at the consumer's mill or at any other suitable place in the United Kingdom. Unless at least half the parcel is available at the mill or in transit for sampling and testing, no test shall be made, and the buyer's claim shall fail, and he shall pay any costs incurred by the seller by reason of the claim.

The samples must be drawn from accurately weighed intact bales as nearly as possible in the manner agreed upon by the British and Scandinavian Pulp Associations and the Paper Makers' Association. At least two per cent. of the parcel must be tested, and in no case less than six bales. The analyst may, if he thinks fit, within three days, test a further two per cent. of the parcel.

The analyst's report as to the result of the test shall be final and binding on the parties, and the costs shall follow the result; but should the excess of moisture or of pulp not exceed half per cent., the original invoice shall stand and the costs shall be paid by the buyer.

(3.) **Force Majeure.**—The buyers or sellers may suspend deliveries under this Contract pending any contingency beyond their control which prevents or hinders the manufacture of paper, or the manufacture or delivery of pulp, viz.:—Act of God, war, strikes, lock-outs, drought, flood, accidents, total or partial fire, unusual obstruction of navigation by ice at the port of shipment, and loss and detention at sea or the like. The sellers or buyers, as the case may be, shall give prompt notice to the other party of the cause and commencement of such suspension, and also when it ceases to have effect, and deliveries shall be resumed as soon as practicable; and in the case of deliveries spread over periods of time, they shall, when resumed, be made at the same rate as provided by this Contract, until the Contract has been completed by delivery and receipt of the full quantity bought and sold, unless otherwise mutually agreed. Shipments in transit must be accepted. If the works of the seller or the buyer are so destroyed as to render them incapable of manufacturing pulp or paper, then notice of re-building must be given within six months, or the other party may cancel.

(4.) **Default in Payment, Bankruptcy or Insolvency.**—If the buyer makes default in any payment in terms of Contract, or becomes subject to the Bankruptcy Laws, or being a Joint Stock Company (whether constituted under British or Foreign Laws) becomes insolvent or goes into liquidation or has a receiver appointed at the instance of the debenture holders or other creditors, the seller shall be entitled to withhold delivery or to refuse to make further deliveries.

(5.) **Default as to Deliveries.**—If during the currency of this Contract the buyer refuses to take delivery of pulp, except for causes within Clause 3 (Force Majeure) he cannot afterwards claim the pulp; but the seller after 14 days' notice to the buyer may re-sell the pulp for the buyer's account at the best price obtainable.

If during the currency of the Contract the seller fails to make a delivery except for causes within Clauses 3 and 4, the buyer, after 14 days' notice to the seller, may buy against the seller at the best price obtainable.

Each delivery under this Contract is to be treated as a separate Contract and failure to give or take any delivery does not avoid the Contract as to other deliveries.

(6.) **Duties.**—Any Customs Duties which may be imposed at Receiving Ports on wood pulp shall be borne by the buyer. Any Export Duties in the country of production shall be borne by the seller.

(7.) **Time Limit.**—All claims by the buyer under this Contract must be made in writing within 14 days after the delivery of the consignment at the consumer's mill, wharf or station in the United Kingdom, and no claim made after the said period will be recognised.

(8.) **Arbitration.**—All disputes arising under this Contract (except as to the quantity of pulp invoiced) shall be settled by Arbitration in the United Kingdom under the Arbitration Act, 1889, and in case of disputes in Scotland or Ireland that Act shall be construed as if it applied to those countries. Each party shall appoint an Arbitrator; and the Arbitrators shall choose their Umpire before proceeding on the reference. If either party fails to appoint his Arbitrator within 14 days after receipt of notice in writing requiring him to do so, the Arbitrator appointed by the other party shall act for both parties, and his award shall bind both parties as if he had been appointed with their joint consent.

If the dispute relates to the quality of the pulp delivered, the Arbitrators and the Umpire must be experts in pulp or paper. At least half the parcel in dispute must be available at the mill or in transit, for their examination, and should they find the pulp not to be reasonably equal to the sample sold upon, they may award that the pulp shall be rejected, or be taken at an adequate allowance.

August 31*st*, 1911.

AMERICA.

New York,_____ 19____

*M*_____

_____

We have this day $\left.\begin{matrix}\text{bought from}\\ \text{sold to}\end{matrix}\right\}$ you

_____on the following terms and conditions, all of which are made a part of this contract, as follows:

Quantity and Description of Goods:—

Mode and Place of Delivery:—

Time of Delivery:—

Price:—

Terms of Payment:—

Remarks:—

Subject to conditions printed on back hereof.

Accepted:—

_____

_____

_____

CONDITIONS.

(1.) **Weight and Packing.**—In all instances where the word "tons" occurs in this contract, it is understood to refer to gross tons of 2,240 lbs. air-dry weight or 1,016 kg. The pulp to be packed in well-pressed bales of declared uniform weight, or a specification to be given with every invoice stating the numbers and weight of each bale. The bales to be covered with good burlap bagging and bound with iron or wire, if not otherwise provided for on the first page of this contract.

(2.) **Moisture**.—All pulp to be billed on air-dry weight, and the term air-dry shall mean 90 per cent. of absolutely dry pulp and 10 per cent. of atmospheric moisture.

(3.) **Tests**.—In case of disputes arising regarding the air-dry contents of the pulp, same to be re-tested at port of arrival, or at the mill of the consumer by a recognized chemist of good standing, according to the custom of the trade, and his report to be final and to be made the basis of settlement. If the difference does not exceed 1 per cent. the invoice stands as rendered. The re-test to be made in following manner:—

Not less than half the parcel in dispute shall be available; otherwise no claim is permissible. Not less than 5 per cent. of the entire shipment in dispute, nor less than six bales to be sampled, and samples to be drawn only from bales in good condition, and the accurate weight of all bales tested to be ascertained by sworn weigher before sampling. The cost of the test to be paid by the party in error.

(4.) **Disputes**.—All disputes as to quality or delivery regarding this contract (with the exception of moisture, which is provided for under clauses 2 and 3) shall be settled by arbitration in the following manner:—

Each party to appoint an arbitrator who shall be well acquainted with the pulp business, and they to appoint their umpire before proceeding with the hearing. If either party fail to appoint their arbitrator within 15 days of notice in writing requiring him to do so, the arbitrator appointed by the other party shall act for both; his decision to be binding upon both parties, as if he had been appointed by consent. It shall be left to the arbitrators in case they agree that the pulp is not of the quality sold within reasonable limits to decide whether or not the pulp shall be rejected or taken with an adequate allowance.

Furthermore, it shall be left to the arbitrators to agree upon the place of arbitration in the United States or Canada.

(5.) Each shipment under this contract to be considered as a separate contract, a default on one or more shipments not to invalidate the rest of the contract, but should two or more deliveries not correspond with the quality purchased, the buyer shall have the option to cancel the balance of this contract.

(6.) This contract is based upon the rate of duty and revenue laws of the United States, as interpreted and applied at the time of making the contract. In case of any increase the buyer has the privilege to cancel this contract, unless the seller is willing to assume the additional duty.

(7.) **Force Majeure**.—The buyer or seller may suspend deliveries under this contract pending any contingencies beyond their control, which prevent or hinder the manufacture of paper or delivery of pulp, viz., Act of God, War, Strikes, Lock-outs, Drought, Flood, Accidents, Total or Partial Fire, Obstruction of Navigation by ice at port of shipment, and loss or detention at sea, Bankruptcy or any other contingency beyond the control of either party. Shipments in transit must be accepted by the buyer.

The seller or buyer, as the case may be, shall give prompt notice to the other party of the cause and commencement of such suspension, and also when it ceases to have effect, and deliveries shall be resumed as soon as practicable thereafter, but deliveries omitted during the period of suspension are to be considered as cancelled and not to be tendered after the expiration of the contract time, unless otherwise mutually agreed.

(8.) **Time Limit**.—All claims of whatever nature must be made in writing within 21 days after the arrival of the shipment at consumer's mill, wharf or station, unless the goods contain defects of quality, which cannot be found on the usual examination on arrival.

(9.) **Place of Delivery**.—The place of delivery is understood to be the consumer's mill, wharf or station, and the buyer shall not be obliged to examine the goods at the European port of shipment.

(10.) **Fulfilment of Contract.**—Failure of the seller to make delivery shall entitle the buyer after due notice of his intention to purchase against the seller for his account, except as otherwise provided for in this Contract.

(11.) **Default or Bankruptcy.**—In case of failure or bankruptcy of the consumer of the pulp bought under this Contract, the buyer shall have the privilege to cancel the undelivered portion of the Contract in this case, by producing the original Contract with the consumer as evidence.

FRANCE.

Bought of:—

Sold to a;—

By the agency of:—

Under the conditions stated at the back of this form.

Quantity and nature of goods:—

Mode and place of delivery:—

Despatch:—

Price:—

Conditions of payment:—

Remarks;—

Subject to the conditions printed or written.

CONDITIONS.

(1.) **Packing and Weight.**—The pulp is to be delivered in bales of a declared uniform weight; otherwise each bale must bear a number to be shown on the Despatch Note with its corresponding weight.

The weight to be understood gross for net. The packing will be a matter of special agreement.

(2.) **Dryness.**—By air dry pulp is understood 90 parts of absolute dry pulp and 10 parts water.

(3.) **Quantity.**—If the buyers dispute the quantity of pulp invoiced the dispute will be submitted to and settled by the Laboratory of the Chamber of Commerce in Paris, or by an expert accepted by both parties. The verification must be made within 15 clear days from the date of the complaint. The chemist or expert must at the buyer's works or depôt, sample immediatelv, verify the dryness of the pulp, and determine the quantity which ought to be invoiced.

In order that a claim shall be permissible, not less than half of the parcel in dispute must be available.

The samples are to be taken in the presence of both parties or their representatives, or in the absence of both parties, by the chemist or expert himself from intact bales exactly weighed, and after the manner agreed upon between the Association of Paper Manufacturers in France and the Association of Scandinavian Manufacturers.

The samples are to be taken from at least 2 per cent. of the bales and from not more than 4 per cent. of the bales invoiced, but in no case on less than six bales, and dried to constant weight at a temperature not exceeding 100° Centigrade. The chemist or expert may at his discretion proceed with a fresh test within three days from the first test. His

judgment will be definite and the cost of the test is to be borne by the party in error. All deficiencies exceeding 20 tons must be replaced on some subsequent occasion by the seller. If the deficiency does not exceed one-half per cent. of the invoiced weight the claim is not to be admitted and the expenses of the test must be paid by the buyer.

(4) **Quality**.—If the buyer proves that the pulp delivered does not fairly represent the usual production of the mill, or sample on which the sale had been effected, the dispute will be submitted to arbitration. The arbitrators will decide if the pulp is to be accepted, refused, or taken at some fixed allowance. For the examination, half of the parcel must be available.

(5.) **Force Majeure**.—The buyers or sellers may suspend all or part of the deliveries under this contract when an independent cause beyond their control prevents either the manufacture of the paper, or the manufacture or delivery of the pulp; in cases of absolute necessity, strikes or lock-outs, war, accidents, fire, loss at sea, accidental drought, flood, stoppage of navigation by ice at the port of shipment, &c.

The party affected by any case of absolute necessity must immediately give notice to the other party, indicating the cause of such suspension with evidence of support. When the suspension ceases to have effect the deliveries shall be resumed according to the production of the sellers or the consumption of the buyers.

Unless understood to the contrary, the quantities not delivered during this suspension will be cancelled if this suspension lasts for more than one month.

In the case of single cargoes or deliveries at longer intervals than a month, one-twelfth of the annual quantity to be delivered shall be cancelled for each month's suspension. However, in cases when the works either of the buyer or of the seller are totally destroyed and not rebuilt, the contract will be null and void for the quantities not yet shipped.

Shipments in transit cannot be refused.

(6.) **Breach of Contract**.—Should the buyer refuse to take delivery of pulp during the currency of this contract, excepting for reasons covered by Clauses 4 and 5, the goods cannot be claimed, but may be sold after 14 days' notice for the account of the buyer. On the other hand, failure of the sellers to make delivery entitles the buyers to purchase for the account of the seller after 14 days' notice.

Each delivery under this contract must be considered as a separate contract, and default of delivery or receipt for a consignment does not vitiate the contract with regard to other deliveries.

(7.) **Default of Payment, Bankruptcy, Insolvency.**—If the buyer makes default in any payment in terms of contract or becomes subject to the laws of bankruptcy, or, being a Joint Stock Company (constituted under the rule of French or foreign laws), becomes insolvent or goes into liquidation, or has a receiver nominated at the demand of the debenture holders or other creditors, the sellers may, at their option, suspend momentarily or definitely the deliveries.

(8.) **Delays**.—All claims must be made in writing within 14 days after the delivery of nine-tenths of the shipment to the mill of the buyer or his depots, and claims posted after this period will not be recognised.

(9.) **Duties**.—In the case of import duties and of other charges being reduced or withdrawn, the price will be reduced in the same proportion. If, on the contrary, new duties are imposed on goods entering France, all costs arising from them will be charged to the buyer.

(10.) **Arbitration**.—All disputes under the present contract will be settled in France by the arbitrators whose decision will be final, no appeal being allowed.

When the arbitration refers to the quality of pulp, the arbitrators shall always be experts in paper or pulp.

Each party shall name a representative, and these two, before proceeding with the arbitration, must name a third arbitrator, charged to settle the matter by a casting vote in case of disagreement.

If the two cannot agree upon the third arbitrator, the latter will be chosen by the President of the Tribunal of Commerce of Paris, from a list drawn up by the Association interested, composed of ten persons. If one of the parties does not name his expert within 14 days' notice, there shall be nominated, at the request of the other party, an expert by the Tribunal of Commerce of Paris. The seller shall select a resident of Paris.

GERMANY.

In Germany no definite form of wood pulp contract note is used. The only printed regulations which have been issued are given below, and these do not invariably form part of the contract of sale.

For Cellulose. Agreed to in 1900.

(1) Cellulose to be invoiced gross for net, the weight of the packing being included, and charged for. The price of the material to be stated in terms of the air-dry weight per 100 kilos. The basis of the air-dry contents to be 88 parts of absolute dry pulp and 12 parts of moisture.

(2) The price to be calculated free on rail. The goods to be sent carriage forward, and the buyer to pay freight. The amount to be deducted on settlement of account.

(3) Invoices payable within 30 days of date, by cash or cheque, at 2 per cent. discount, or in 3 months' bills without discount.

(4) The supply of pulp, unless expressly arranged otherwise, is for the consumption of the buyer only.

(5) Strikes, shortage of coal and serious disturbances in process of manufacture shall release the parties from delivery or acceptance of the goods according to the time and extent of the trouble.

For Ground Wood. Agreed to in 1900.

(1) The invoices to be calculated on 100 kilos. air-dry pulp. The basis of air-dry contents to be 12 per cent. moisture in the air-dry pulp above the absolute dry weight.

(2) The price to be fixed as at the pulp factory or delivered free to buyer.

(3) In the latter case the goods to be sent carriage forward, and the buyer to pay freight. This amount to be deducted on settlement of account.

(4) The invoices payable within 30 days in cash with 2 per cent. discount, or in 3 months' bills without discount.

PULP WOOD MOISTURE CERTIFICATE.

This is to Certify that I have tested for moisture a parcel of Pulp, said to consist of bales, marked ying at

The samples were drawn by on

The sample of pulp contained :—Absolute dry pulp, per cent.

Total moisture, per cent.

The percentage of Air dry pulp in the sample is :—per cent.

(Basis : 90 parts absolute dry = 100 parts air dry)-

	Bales.	Kilos.	Tons. cwt. qrs. lbs.
Gross Weight of Bales sampled			
Calculated weight of Parcel ...			
Weight of Parcel, if invoiced air dry			
Weight of Parcel, if invoiced 50% moist			
Weight of Pulp according to Invoice			

NUMBERS AND DETAILED WEIGHTS OF BALES SAMPLED.

Analyst.

X. Useful Tables.

No. 1. Volume and Weight of Wood Pulp.

Description of Pulp.	Number of cubic feet in one bale.	Cubic feet required for storing pulp per bale.
Moist Mechanical, 4 cwt. bales ...	8·75	10.0
Dry Sulphite, 2½ cwt. bales ...	8·00	8.5

No. 2. Cubic Feet per Ton (1,016 Kilos.).

Description of Pulp.	Calculated from a single bale.	Calculated from a small stack of bales.
Moist Mechanical in 4 cwt. bales, (448 lbs.)	43·75	50·0
Dry Sulphite in 2½ cwt. bales, (280 lbs.	64·00	68·0

Note.—The space required for stacking pulp is in excess of the actual cubical contents of the single bale, being 12-14 per cent. in the case of moist mechanical and 8-10 per cent. in the case of dry sulphite.

No. 3.—Table of Equivalents for Measurement of Wood.

	Cubic fathoms.	Cubic feet.	Cubic Metres.	Cords.
One cubic fathom is	—	216	6·113	1·0687
One cubic foot is ...	0·00463	—	0·283	0·00781
One cubic metre is	0·163	35·314	—	0·276
One cord is ...	0·5926	128	3·6224	—

No. 4.—Decimals of a Ton, from 1 lb. up to 1 cwt.

	0 Qrs.	1 Qr.	2 Qrs.	3 Qrs.
lbs. 0	—	·01250	·02500	·03750
1	·00044	·01294	·02544	·03794
2	·00089	·01339	·02589	·03839
3	·00133	·01383	·02633	·03883
4	·00178	·01428	·02678	·03928
5	·00223	·01473	·02723	·03973
6	·00268	·01518	·02768	·04018
7	·00312	·01562	·02812	·04062
8	·00357	·01607	·02857	·04107
9	·00401	·01651	·02901	·04151
10	·00446	·01696	·02946	·04196
11	·00491	·01741	·02991	·04241
12	·00536	·01786	·03036	·04286
13	·00580	·01830	·03080	·04330
14	·00625	·01875	·03125	·04375
15	·00670	·01920	·03170	·04420
16	·00714	·01964	·03214	·04464
17	·00759	·02009	·03259	·04509
18	·00803	·02053	·03303	·04553
19	·00848	·02098	·03348	·04598
20	·00893	·02143	·03393	·04643
21	·00937	·02187	·03437	·04687
22	·00982	·02232	·03482	·04732
23	·01026	·02276	·03526	·04776
24	·01071	·02321	·03571	·04821
25	·01116	·02366	·03616	·04866
26	·01160	·02410	·03660	·04910
27	·01205	·02455	·03705	·04955

No. 5.—Table of Pounds Avoirdupois equivalent to Kilograms.

Kilogs.	0	1	2	3	4	5	6	7	8	9	Kilogs.
0	—	2·204	4·409	6·613	8·818	11·023	13·227	15·432	17·637	19·841	0
10	22·0462	24·250	26·455	28·660	30·864	33·069	35·273	37·478	39·683	41·887	10
20	44·0924	46·297	48·502	50·706	52·911	55·116	57·320	59·525	61·729	63·934	20
30	66·1386	68·343	70·548	72·753	74·957	77·162	79·366	81·571	83·776	85·980	30
40	88·1848	90·389	92·594	94·799	97·003	99·208	101·413	103·617	105·822	108·026	40
50	110·231	112·436	114·640	116·845	119·050	121·254	123·459	125·663	127·868	130·073	50
60	132·277	134·482	136·686	138·891	141·096	143·300	145·505	147·710	149·914	152·119	60
70	154·323	156·528	158·733	160·937	163·142	165·347	167·551	169·756	171·960	174·165	70
80	176·370	178·574	180·779	182·984	185·188	187·393	189·597	191·802	194·007	196·211	80
90	198·416	200·620	202·825	205·030	207·234	209·439	211·644	213·848	216·053	218·258	90

No. 6.—Table of Kilograms equivalent to lbs. Avoirdupois.

lbs. Avoir.	0	1	2	3	4	5	6	7	8	9	lbs. Avoir.
0	—	·4535	·9071	1·3607	1·8143	2·2679	2·7415	3·1751	3·6287	4·0823	0
10	4·5359	4·9895	5·4431	5·8967	6·3503	6·8039	7·2574	7·7110	8·1646	8·6182	10
20	9·0718	9·5254	9·9790	10·4326	10·8862	11·3398	11·7934	12·2470	12·7006	13·1542	20
30	13·6078	14·0614	14·5150	14·9686	15·4222	15·8757	16·3293	16·7829	17·2365	17·6901	30
40	18·1437	18·5973	19·0509	19·5045	19·9581	20·4117	20·8653	21·3189	21·7725	22·2260	40
50	22·6796	23·1332	23·5868	24·0404	24·4940	24·9476	25·4012	25·8548	26·3084	26·7620	50
60	27·2155	27·6691	28·1227	28·5763	29·0299	29·4835	29·9371	30·3907	30·8443	31·2978	60
70	31·7514	32·2051	32·6587	33·1122	33·5658	34·0194	34·4730	34·9266	35·3802	35·8338	70
80	36·2874	36·7410	37·1946	37·6482	38·1018	38·5554	39·0090	39·4626	39·9162	40·3697	80
90	40·8233	41·2769	41·7305	42·1841	42·6377	43·0913	43·5449	43·9985	44·4521	44·9057	90

No. 7.—Equivalent of Qrs. and Lbs. in Kilograms.

On basis that 1 ton (2,240 lbs.) = 1,016 kilos.

Lbs.	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Qrs. 0	—	·4536	·9071	1·3607	1·8144	2·2680	2·7214	3·1750	3·6285	4·0821	4·5357	4·9893	5·4431	5·8966
1	12·700	13·153	13·607	14·060	14·514	14·968	15·421	15·875	16·329	16·783	17·236	17·689	18·143	18·596
2	25·400	25·853	26·307	26·760	27·214	27·668	28·121	28·575	29·029	29·482	29·936	30·389	30·843	31·296
3	38·100	38·553	39·007	39·460	39·914	40·368	40·821	41·275	41·729	42·182	42·636	43·089	43·543	43·996

Lbs.	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Qrs. 0	6·350	6·804	7·257	7·711	8·164	8·618	9·071	9·525	9·979	10·432	10·886	11·340	11·793	12·247
1	19·050	19·504	19·957	20·411	20·864	21·318	21·771	22·225	22·679	23·132	23·586	24·040	24·493	24·947
2	31·750	32·204	32·657	33·111	33·564	34·018	34·471	34·925	35·379	35·832	36·286	36·740	37·193	37·647
3	44·450	44·904	45·357	45·811	46·264	46·718	47·171	47·625	48·079	48·532	48·986	49·440	49·893	50·347

Examples.—cwts. qrs. lbs. 0 3 17 = 45·811 kilos.

42 kilos. = a weight between qrs. lbs. 3 8 and qrs. lbs. 3 9.

No. 8.—Equivalent of Cwts. and Qrs. in Kilograms.

On the basis One Ton (2240 lbs.) = 1016 kilos.

Cwts.	0 Qrs.	1 Qr.	2 Qrs.	3 Qrs.
1	50·80	63·50	76·20	88·90
2	101·60	114·30	127·00	139·70
3	152·40	165·10	177·80	190·50
4	203·20	215·90	228·60	241·30
5	254·00	266·70	279·40	292·10
6	304·80	317·50	330·20	342·90
7	355·60	368·30	381·00	393·70
8	406·40	419·10	431·80	444·50
9	457·20	469·90	482·60	495·30
10	508·00	520·70	533·40	546·10
11	558·80	571·50	584·20	596·90
12	609·60	622·30	635·00	647·70
13	660·40	673·10	685·80	698·50
14	711·20	723·90	736·60	749·30
15	762·00	774·70	787·40	800·10
16	812·80	825·50	838·20	850·90
17	863·60	876·30	889·00	901·70
18	914·40	927·10	939·80	952·50
19	965·20	977·90	990·60	1003·30
20	1016·00			

Cwts. qrs. lbs.

Example ... 12 3 0 = 647·70 kilos.

IX.—Table of Metrical Units.

One millimetre = ·03937 inches.	One inch = 25·4 millimetres.
One metre = 1·0936 yards.	One yard = 0·9144 metres.

One gramme = ·0022 lbs.	One lb. = 453·59 grammes.
1000 kilos = 0·98 tons.	One ton = 1016·04 kilos.
1000 kilos = 19·60 cwts.	One cwt. = 50·802 kilos.

One cubic centimetre = ·061 cubic inches.	One cubic inch = 16·387 cubic centimetres.
One litre = ·22 gallons.	One gallon = 4·546 litres.

One sq. centimetre = ·155 sq. inches.	One sq. inch = 645·16 sq. centimetres.
One sq. metre = 10·764 sq. ft.	One sq. foot = ·0929 sq. metres.

One kilo per sq. centimetre	= 14·223 lbs. per sq. in.	One lb. per sq. inch	= ·0703 kilos per sq. centimetre.
One gram per sq. metre	= 2048 lbs. per sq. ft.	One lb. per sq. foot	= 4·882 kilograms per sq. metre.

Grams per litre = Lbs. per 100 gallons.	Grains per gallon = ·01428 grammes per litre.

PART II.

THE BLEACHING OF WOOD PULP.

I. Introduction.

Want of Standards.—The position occupied by wood pulp as a material for the manufacture of all kinds of paper gives the subject an importance which cannot be overrated. The matter requires consideration from three points of view, though it is difficult to state the precise order in which these should be discussed, as they are all of equal importance.

These three points are the *economy* of the operation, the *results* obtained, and the actual *method* of bleaching.

The raw material is extremely varied in composition, and in its behaviour towards a solution of bleaching powder exhibits many peculiarities.

The wood pulps usually met with can be roughly classified as follows:—

(1) Easy bleaching pulps.
(2) Moderately easy bleaching pulps.
(3) Pulps difficult to bleach.
(4) Non-bleaching pulps.

These terms are somewhat indefinite, for the clasification is largely a matter of opinion, and paper makers would not classify a number of pulps in the same way. This indefiniteness largely arises from a want of a standard to which the wood pulp in its relation to bleaching shall be referred. What is to be selected as a standard? Shall the colour of a bleached pulp be regarded as a standard, or the percentage of bleaching powder consumed in a given time? Or shall the percentage of bleach used to produce a certain colour be taken as the standard? In actual practice this latter is really the course

adopted by each paper maker for himself, but the standards of one paper maker are not the standards of another, and therefore the adoption of a "colour" reference is difficult.

This question of "standard of reference" is not the only one which is interesting to paper makers. Another question is the study of the conditions which regulate the bleaching of the wood pulp. The paper maker desires to know what are the conditions which modify the consumption of bleach required to produce a colour which will give him satisfaction. He also desires to be able to regulate all the variable conditions so as to produce a definite colour or to reduce the time occupied in bleaching, and thus as one of the final results bring down the cost of bleaching to a minimum.

Process of Bleaching.—The methods by which the bleach used for a given pulp is arrived at may first be discussed. In doing this it is necessary to pay attention to the chemical changes taking place during the whole process, and to study the action of the bleach liquor from the time that it comes into contact with the pulp. Apparently the reaction between the pulp and the bleach liquor is a simple one, though actually the changes which go on are complicated. To the superficial observer it is merely a question of plenty of bleach, plenty of agitation, and the gradual change of the wood pulp into a purely white fibre.

But it may be shown that the process is not so simple, since the action of the bleach liquor on compounds other than those actually present in the pulp at the commencement of the operation must be studied, compounds produced by the bleach itself in the earlier stages of the change.

With regard to the pulp itself it is important to measure the influence of the degree of purity of the pulp, because the great differences found in actual practice as to the amount of bleach consumed can only be accounted for by referring to the constitution of the pulp. In other words, elements are present in the pulp which cause a high consumption of bleach, and it must be shown that those constituents are absent in what is known as an "easy bleaching pulp."

Further, the answers to such questions as the probable yield of bleached pulp from a given weight of the raw material, and the economy or otherwise of using inferior brands

of pulp need careful attention. Price is not always the measure of value. A pulp which can be purchased at £7 10s. per ton may be a better pulp than one which is offered at £8. On the other hand, a high priced pulp for which perhaps £12 is being asked may be far superior to one offered at £10, although it may not have the appearance and handle of a superior quality.

The value of the wood pulp is not entirely determined by its strength and its behaviour on the paper machine. In the case of pulps which are employed because they come under the definition of an "easy bleaching pulp," the cost of the bleaching process and the ultimate yield of pure fibre are frequently more important factors.

The extent to which the original wood has been affected either by the sulphite or soda process bears a close relation to the bleaching properties of the pulp.

In general terms it may be stated that the amount of bleaching powder used per ton of pulp varies in proportion to the severity or completeness of the boiling operations. The production of an "easy bleaching pulp" depends mainly on an exhaustive treatment of the wood with the sulphite or soda liquors. The yield of pulp is naturally much lower in such cases, but the subsequent loss of fibre and the bleach consumption in producing a white pulp is correspondingly less.

On the other hand, a moderate boiling treatment gives a higher yield of pulp, which, however, requires more bleaching powder, and gives a lower yield of white pulp, the loss of weight on bleaching being an item which cannot be ignored.

II. Post Samples and Trial Deliveries.

Vague Definitions.—When the subject of bleaching pulp is considered from a commercial point of view there are many points of value and interest. The disputes and difficulties which arise from time to time in the commercial dealings between buyer and seller arise from a lack of appreciation of the technical side of the subject. The probability is that these disputes arise from a certain ambiguity of terms in several ways.

(1) The description of the pulp is extremely indefinite, and such phrases as "easy bleaching, prime bleaching, special, first quality, second quality," and the like, do not afford any real indication of the quality of the pulp, since different interpretations are placed upon the terms employed.

(2) The wording of contracts in respect of the quality and behaviour of the pulp sold as *bleaching* pulp, is also open to a good deal of criticism, and there is little doubt that the looseness of terms employed coupled with the lack of definition in respect of the condition of the pulp, is responsible for a good deal of trouble.

(3) The question of the experimental methods of bleaching also call for some comment, though perhaps this might not always be regarded as a commercial question.

It is evident that the subject of "standards for bleaching wood pulp" will have to receive almost as much attention as that devoted to the eternal question of "moisture in wood pulp."

The result of this indefiniteness as to the descriptions used, the terms of the contract, and the absence of standard methods for testing, is to be seen in the various disputes which arise

from time to time, and in the fact that frequently either the pulp manufacturer or the paper maker gives way in order to save trouble. When the dispute reaches an acute stage, necessitating the appointment of arbitrators, the difficulty is often accentuated, because the want of standards in the three items set out is still felt, and the arbitrators are often in the position of trying to settle the matter by reference to trade custom, which in itself varies considerably, according to local conditions.

It is evident, from these simple considerations of the commercial aspect of the question, that the subject of the bleaching of wood pulp needs to be thoroughly ventilated.

Post samples.—The first question which is naturally prominent is that of *post samples*. The initial development of a possible dispute is frequently due to the sample which is received by the paper maker. It is somewhat surprising that any business should be done on the strength of small sheets such as are usually received through the post. Frequently these samples are sent unstamped, with no marks of identification, or any adequate description. It may be said, however, that such samples are in most cases merely received and accepted as an indication of the general appearance and handle of the bulk, some regard being paid of course to its colour.

With high-class *easy bleaching* pulps, using this term in its generally accepted sense, the post sample often affords the paper maker sufficient evidence as to bleaching properties, but it is with the lower grades of such pulps that the lack of standards makes itself felt. So long as a post sample is not regarded as an absolute and exact representation of the main bulk, it serves a useful purpose, being indeed the only method of opening up negotiations. These samples should always bear upon them the official stamp of the selling agents, and also an adequate description, so that should they be referred to later on there can be no question as to identity. In the case of disputes arising over a post sample, these marks of identification on the sheet would save considerable trouble if evidence were needed as to the source from which it was obtained.

If the small sheets are ever used as the basis of a contract, then it would be advisable for the contracting parties to adopt

some system by which each of them could retain one-half of the post sample, the respective halves to bear the stamp and signature of the two contracting firms. In this way any question as to the identity of original samples would be beyond dispute. Such procedure would also ensure the existence of a sheet of pulp which could be submitted to a chemist for investigation and analysis.

The large increase in the demand for pulps that can be bleached has brought the matter into prominence, and the limitations of the value which should be attached to a post sample are fairly well understood.

Trial Deliveries.—As a general practice, the paper maker prefers to purchase a trial lot of pulp containing one or two tons, and to examine the behaviour of the pulp on a large scale. In such cases sufficient material is taken to fill one or two potching engines or similar appliances used for bleaching pulp, and to determine the colour of the pulp produced by the addition of the amount of bleaching solution employed with other pulps which have proved satisfactory.

This procedure is good in many respects, provided that a representative number of sheets are drawn from the bulk sample and retained for purposes of comparison. It frequently happens that the whole of the sample delivery is used in preliminary trials, and it is not surprising to find that troubles occur later on with subsequent deliveries accepted under contracts based on the behaviour of small sample deliveries. The paper maker contends that he was able to bleach the first consignment with 12 per cent. of bleaching powder for example, and that the bulk delivery required 15 per cent. On the other hand, the pulp manufacturer insists that the bulk is equal to sample. In the absence of any agreed standard, and with no sheets available from the sample delivery, it is manifestly impossible to arrive at the actual facts of the case.

In dealing with this subject of sample deliveries the proper course to pursue in order to avoid disputes is fairly obvious, and the following plan seems to recommend itself:—

Assuming that the sample delivery consists of 5 tons of bleaching pulp packed in the form of 50 bales, each weighing 2 cwt., sheets should first be drawn from the bales and retained as a representative sample of the trial consignment. The con-

tracting parties might have these sheets drawn say from each bale, or one from every third or fourth bale according to arrangement, such sheets to be drawn in the presence of a representative of each of the parties concerned. The sheets should be cut in half, and each half stamped by the respective firms and duly sealed up so that both buyer and seller would be in possession of a fair average sample of the trial delivery.

In the case of any subsequent dispute these authenticated samples could be referred to, for instance, in the event of an arbitration. It may be reasonably suggested that this would involve a good deal of trouble which might be of frequent occurrence if the consignments were in small quantities. This is perfectly true, and the method to be adopted must largely be determined by the circumstances of each case. Such methods need only be suggested as being likely to provide authenticated samples and data which could be relied upon in the event of disputes which occur more frequently with inferior grades of bleaching pulps.

Bulk Samples.—Some paper makers adopt a wise precaution in dealing with the sample delivery by reserving the major portion of it for comparative tests against the consignments sent under a contract. An instance of this might be quoted. With a small trial order of 5 tons, comprising 50 bales, the condition of the pulp could be determined with about 10 bales, this quantity being sufficient for an average size beater. The results being satisfactory, a contract for 400 or 500 tons would be made, the pulp to be forwarded in quantities of 80 or 100 tons at a time. The condition of each of the deliveries under the contract could be compared with the standard sample each time, since 50 bales would give five lots of ten bales each, and the delivery of the pulp itself would be complete in five lots. In this way each of the 80 or 100 ton lots delivered could be tested and compared with the standard pulp.

A systematic method of this description is often regarded as a nuisance, partly because it is necessary to store the standard pulp by itself, and partly because the amount of available storage room is small, But in the absence of any standard method of recording the bleaching properties of a pulp, and for want of proper definitions which could be applied to the pulp in question such methods as this must be adopted. The differ-

ence in the behaviour of various pulps when bleached are so great that precautions of some kind are absolutely necessary.

It has been suggested that the institution of some scale of bleaching properties could only be affected by a proper classification such as the following :—

Description of Pulp.	Percentage of Bleach Powder Required.
Very easy bleaching	5 to 6
Easy bleaching	6 to 7
Special	7 to 8
Prime	8 to 10
Bleaching	10 to 12
First quality	12 to 14
Second quality	15 to 20
Mixed	20 and over.

III. Mill Practice and Conditions.

THE empirical methods adopted for arranging contracts in the sale of wood pulps call for some radical change, if disputes are to be avoided. This change can only be bronght about satisfactorily by devising some scheme acceptable to all parties concerned, and by substituting a record of actual facts for what is at present an expression of personal opinion.

The loose indefinable terms, *easy bleaching*, *first quality*, *second quality*, and similar phrases will have to be abolished, or at any rate, rendered definite by the addition of further qualifications capable of being expressed in numerical terms. In other words, the amount of bleach required to whiten the pulp should be stated, either as a percentage or in the form of the weight of bleach required per ton of air dry pulp.

This proposition seems at first sight so simple as to call for little dissent, but in reality the question is complicated in many ways, and the adoption of a standard method of recording the value of the pulp in terms of the percentage of bleach consumed could not be agreed to without an adequate discussion of the conditions.

Bleach consumption.—A case which would at once appeal to the pulp agent may be stated and then examined. A certain brand of a high-class pulp is supplied to two mills. On making a practical trial, one mill reports the bleach as good, requiring only 8 per cent. of bleach, but the other mill is dissatisfied because the consumption is 10 per cent. Assuming the pulp is uniform, how is this difference to be accounted for? The agent says, *sotto voce*, "You don't know how to bleach pulp." This may be true, but it does not answer the question.

Now a difference like this, and larger differences, may be due to causes which have nothing to do with the pulp, seeing that we start with the assumption that the pulp is absolutely uniform.

The conditions of bleaching in the first mill may be thoroughly

up-to-date, so that all pulps can be bleached with the minimum of powder, while in the second the plant and methods may be putting it mildly, somewhat antiquated. Is the pulp manufacturer to take this into account? Would he not argue that the pulp bleaches with 8 per cent., and contend that the additional 2 per cent. consumed in another mill is no concern of his? He probably would.

Quality of Powder.—In seeking to explain this extra 2 per cent. there are many directions in which the enquiry might be turned. At the very outset we have the bleaching powder itself to consider. If one mill is using a so-called good bleach, invoiced at 36 to 37 per cent., and the second is using a powder also described as a good bleach, which happens to contain only 34 per cent. of available chlorine, a slight discrepancy at once occurs. Then the system of preparing the clear solution may be faulty at one of the mills. It is certain that the treatment of the dry powder in many paper mills even in these days of progressive management is not all that it might be. Suppose the first mill by an efficient system of lixiviation is able to produce 210 gallons of liquor standing 6 Twaddel from 112 lbs. of powder testing 36·5 per cent. of available chlorine, and the second only 190 gallons from a powder of identical strength. Each paper maker, for practical purposes, reckons that he has exhausted the powder and taken out all the soluble matter.

Hence if 190 gallons of liquor is sufficient to bleach half a ton of pulp in both mills to a good colour, the second paper maker uses all his liquor, and of course calculates that as equivalent to 112 lbs. of bleaching powder. The first also uses 190 gallons of liquor, which he calculates as equivalent to 101·4 lbs. of powder, and he still has in stock 20 gallons equal to 10·6 lbs. of powder.

Imperfect Lixiviation.—Apparently, therefore, the pulp is bleached with 10 per cent. of powder in one mill, but in the other the consumption is only 9 per cent. Actually the quantity of active chlorine used is the same in both, other conditions being equal, but owing to the inferior system of lixiviation in the second mill, the percentage of powder appears to be greater.

This is a point of considerable importance which is easily

overlooked. The question becomes accentuated if in addition to want of care in preparation of the liquor the strength of the powder is not taken in account.

Continuing the illustration further: If the first mill is using bleach testing 36·5 per cent. and the second is using bleach testing 35·0 per cent. chlorine, what is the result in terms of the percentage of powder required to bleach a pulp?

If in the second mill the powder is lixiviated in the usual way, the amount of active chlorine per 112 lbs. of powder is of course less, and the volume of liquor obtained would only measure 182 gallons instead of 190. (Note.—This figure is arrived at by using the proportion of 36·5 to 35·0 per cent. for calculation. As a matter of fact the volume would not be reduced quite to this extent, as soluble substances other than hypochlorite of calcium would tend to keep up the density).

To get a volume of liquor containing as much active chlorine with this inferior powder, as was used in the first trial, the second paper maker must apparently add liquor to the pulp equivalent to 117 lbs. of powder.

190 : v = 36·5 : 35·0. Volume is 182 gallons.
182 galls. is reckoned as produced from 112 lbs. powder.
Hence 190 galls. means 117 lbs. of powder.

We have already stated that the problem is not altogether a simple question of calculation, because chemical changes in the quality of the solution are not reckoned with. This will not affect, however, the material fact that the consumption of bleach will appear to be greater owing to the use of a slightly inferior powder.

The consumption of powder would then appear to be 10·5 per cent, on the weight of pulp, These instances are not by any means far fetched, though it does not follow that the errors would always go in one direction. It would be possible to have the error due to incomplete washing neutralised by the advantage of a bleach having a high percentage of available chlorine.

Methods of Bleaching.—The enquiry as to the reason why one mill may report a pulp as consuming only 8 per cent. of bleach, and a second mill appears to use 10 per cent. is not always settled by a study of the system employed for preparing the bleach liquor. The two mills in question might be equally equipped in the matter of lixiviating plant, and able to produce

an equal volume of liquor from 112 lbs. of dry bleach, and yet report a difference in the bleaching quality of the pulp.

It is necessary to consider the influence of different methods of bleaching and the variations in mill practice which tend to produce dissimilar results, as expressed in terms of the percentage of bleach powder consumed.

The purity of colour ultimately obtained is greatly influenced by such factors as temperature, proportion of water to air-dry pulp, strength of liquor used, soluble constituents in the pulp itself, and other factors of equal importance.

Varied Conditions.—Now if we add to these considerations the results of different methods of bleaching, such as—

(1) Steeping the fibre in the bleach liquor at ordinary temperature until perfectly white;
(2) The circulation of pulp and bleach in the ordinary potcher;
(3) The treatment of the mixture in such machines as the "Tower" apparatus;
(4) Electrolytic systems of bleaching;
(5) The application of a continuous system of bleaching,

we find elements calculated to create varying results.

It would seem impossible, therefore, to lay down conditions for any bleaching trials at a mill which would be fair to all parties. The pulp maker would probably argue that the pulp should be judged as to its bleaching qualities by its behaviou at a mill which was provided with the latest up-to-date appliances for treating the pulp with a minimum percentage of bleaching powder. The paper makers would scarcely agree to such an argument; first, because they would naturally object to be compelled to put down special plant; and, secondly, because the actual percentage of bleach used does not always indicate that the operation has been conducted economically. For instance, if one paper maker is able to bleach pulp with 9 per cent. of powder at a cost includin material, labour, allowances for motive power, and other standing charges at 13s. per ton of pulp, and a second paper maker is able to bleach for 12s. a ton in spite of using 10 per cent. of bleach powder, the case is open to considerable discussion, and would probably end in favour of the paper maker.

The Measure of Efficiency.—Admitting that the minimum percentage of bleach powder is not always a correct measure of the efficiency and economy of a mill plant, we are bound to refer to some standard which would most nearly meet an average case. This means that the bleaching qualities of a pulp would have to be determined under exact conditions such as can be obtained only in the chemical laboratory.

Now in the laboratory it is possible to devise methods for treating the pulp so as to ensure a minimum consumption of bleaching powder, but the arguments which we have already suggested in reference to this matter as applied to bleaching trials made at a paper mill apply with equal force to experiments made in the laboratory. It would be worse than useless with our present knowledge of practical methods of bleaching to adopt a method for bleaching pulp in the laboratory that could not be utilised in some form with advantage in the paper mill.

It might be argued, therefore, that any standard system of measuring the bleaching qualities of a pulp in the laboratory must be worked out along lines which are generally acknowledged to represent the average mill practice.

The whole question of the definition or classification of wood pulps in view of bleaching qualities appears to hinge upon the desirability of substituting a "bleach consumption" figure for the present vague descriptions.

How far would the adoption of a rigid method for determining the percentage of bleaching powder consumed meet every case? That is a difficult question to decide for pulps behave so differently. In some cases a high colour is best obtained by giving the pulp a good washing with hot or cold water before adding bleach; in other instances a preliminary treatment with a small quantity of bleach, followed by a little washing, and then the repetition of bleach gives good results, which cannot be obtained any other way.

With refractory pulps, some modification of the ordinary process is almost essential, and the question of a laboratory method applicable to all pulps becomes imperative.

IV. Other Conditions which affect Bleach Consumption.

Use of Residual Liquors.—In considering the factors which determine the consumption of bleach, and the colour of the ultimate product, we must not overlook the influence of the products of the bleaching, which for the most part are in a soluble form mixed with the pulp. It is now generally recognised that the use of back liquors from the bleaching of a fibre is not only of no value, but that in most cases it is positively detrimental.

Perhaps the idea of back liquors containing any available chlorine arose from the too frequent use of the Twaddell hydrometer, in conjunction with the occasional application of a specially prepared solution of starch paste and potassium iodide. The latter gave a decided blue colour with traces of bleach, and then since the hydrometer might indicate one or two degrees Twaddell, the assumption of a valuable back liquor was inevitable. The limits of usefulness of the hydrometer as an indicator of *chemical* strength, as contrasted with mere *density*, are now well known, so that a better conception of the real condition of the back liquors has arisen.

The only circumstances under which residual liquors could be used with any advantage occur in mills where water is scarce or expensive. In such cases the pulp from boiling operations might be washed with the residues, not so much for the purpose of using any traces of bleach, but more with a view of economising washing waters.

Now these conditions do not happen with wood pulp, which is supposed to be a well washed material when supplied to the mill, but so far as the possibility of economy by using back liquor is concerned, the principles involved are of a similar character.

Composition of Residual Liquors.—The liquors left after the bleaching of wood pulp are of complex composition. They contain soluble organic compounds, resinous matters, lime salts, and oxidised hypochlorites. Temperley gives the analysis of such a wood pulp liquor as follows :—

	Lbs. per 1,000 gallons.
Mineral residues, chiefly calcium chloride	126·6
Organic residues, volatile on ignition	62·0
Total solids, dried at 100° C.	188·6

The surface scum obtained from the liquor had the following composition :—

	Lbs. per 1,000 gallons.
Resinous matter...	2·17
Lime	·80
Moisture	8·90
Fibre	2·40
Total	14·27

Now these compounds in solution in residual liquors are very unstable, and react easily with the hypochlorite of fresh bleaching powder, so that the employment of washings in conjunction with raw bleach solution must result in a greater consumption of powder per ton of air-dry pulp.

Temperley has shown this by some interesting experiments made in 1901, and we quote these as illustrating an important factor in economical bleaching. Definite quantities of bleach solution were added to known volumes of ordinary water, and similarly to equal volumes of a carefully filtered residual liquor from the bleaching of a sulphite pulp. The solutions were tested for a period of four hours at different temperatures, the results being very different in character.

EXPERIMENTS WITH ORDINARY WATER.

Solution.	Temperature used.	Bleaching Powder used. Grains per gallon.	Bleaching Powder used. Lbs. per 1,000 gallons.
Water	70° ...	4·20 ...	0·60
Water	90° ...	4·90 ...	0·70
Water	120° ...	9·10 ...	1·30

EXPERIMENTS WITH RESIDUAL LIQUORS.

Solution.	Temperature used.	Bleaching Powder used. Grains per gallon.	Lbs. per 1,000 gallons.
Liquor	70° ...	191·20 ...	27·30
Liquor	90° ...	248·50 ...	35·50
Liquor	120° ...	784·00 ...	112·00

The figures here show that residual liquors, even if practically colourless, are positively detrimental to efficient bleaching. Practical work demonstrates this, not only from the point of view of consumption, but what is often of greater importance, from the point of view of colour. The same defect is found to a lesser degree in the use of unfiltered water, or water coloured by vegetable matter in solution.

Effect of preliminary washing of the pulp.—During the course of some investigations as to the possibility of modifying the methods of bleaching, the effect of washing the pulp with water before actually bleaching it was studied, so as to determine the influence of any soluble constituents upon the rate of bleach consumption, and the colour of the final product.

The laboratory trials indicated that in some cases such a process might be adopted with advantage in the mill. Thus a preliminary washing with water, generally speaking, causes a more rapid consumption of the bleach with a production of a much better colour as compared with the ordinary method.

In one trial a pulp consumed 12·5 per cent. of bleach when first extracted with water in three hours. Under ordinary conditions this pulp only consumed 11·00 per cent., but there was no comparison of colour, the former being infinitely better.

In another case with three hours' bleaching a pulp, after a preliminary extraction with water, gave a very good colour consuming 7·5 per cent. bleach, and only a moderate colour consuming 6 per cent. of bleach in the ordinary way. It is to be noted that the further consumption of 1·5 per cent. in the latter instance did not bring up the colour equal to the former.

Here in these particular instances the removal of some soluble matters from the wood pulp has improved the final bleaching effect.

It would appear reasonable to suppose that the operations conducted on a large scale would give similar results. Such is not the case, however, for in the mill, the element of "bulk"

enters largely into the question. It is true that with the laboratory trials one may readily use the pulp and bleaching solutions in the proportions which obtain in the mill, but certain effects are produced with operations on the large scale which escape the attention of the operator working on a small scale. Thus in the washing of pulp in large quantities resinous matters are mechanically liberated and gradually accumulate in the form of sticky tenacious masses which give endless trouble. The appearance of resinous matter of this description on the sides of beating engines has long been known, and its accumulation has been greatly aggravated during a process which at first sight seems likely to give beneficial results.

The element of "bulk" is an important factor in many chemical operations. For example, with certain chemical reactions it is necessary to conduct the operations at a low temperature, not allowing the solutions to get heated. On a small scale it is comparatively easy to keep a temperature down, but in working with large bulks and quantities, the reduction of temperature is not so easy, as large quantities of solution cannot be cooled very quickly.

The influence of the soluble constituents upon the consumption of bleach and the ultimate colour may easily be studied by determining the bleach required after removal of some of these bodies.

The great variation in the composition and quality of the wood pulps offered makes a thorough investigation of the whole subject a matter of importance. The pulp manufacturer raises the quality of his product by boiling the wood for a greater length of time, or by the use of a stronger liquor. The precise effects of these altered conditions in terms of the chemical constitution of the wood pulp obtained are not accurately known, although the practical results in the shape of an "easy bleaching" pulp are.

Laboratory Results and Mill Practice. — The point which may be open to question is the obligation on the part of the paper maker to arrange the mill plant and the bleaching operations on a large scale so as to secure working conditions likely to ensure a minimum consumption of bleach. Naturally the paper makers require a pulp to attain a proper colour with the plant at his disposal. On the other hand the pulp maker

having ascertained the minimum quantity of bleach which will whiten his pulp objects to be responsible for any increased consumption arising from defective or insufficient plant.

It is quite easy under such circumstances to find the mill consumption 4 to 5 per cent. greater than a laboratory test. Hence it becomes a matter of some considerable importance to arrive at the exact causes of any such difference. Careful investigation along the lines already suggested will locate the difficulty, and it should be possible to distribute the extra consumption under the proper causes. This confirms the advisability of measuring the influence of temperature, time, proportion of water to air-dry pulp, the use of considerable excess of bleach liquor and other factors.

Effect of Temperature.—The relation of temperature to the subject of wood pulp bleaching involves many important questions, examples of which we have already given. The curious effect of *local action*, for example, is one of these. When live steam is blown direct into pulp which is not kept in constant circulation, the pulp gets overheated in parts. The immediate effect is not always seen in actual practice, but a very simple laboratory experiment will show it.

In a large shallow hand-basin place a known weight of pulp broken down to a proper consistency with water. Stir in the required amount of bleach solution. Heat the basin by means of a spirit lamp or Bunsen burner (using a small flame), placed close up underneath, about half-way between the centre of the bottom of the basin and the outer circumference. Note the gradual bleaching of the pulp immediately above the flame in the basin, while the remainder of the pulp keeps its original colour. Do not disturb the pulp during this experiment. Test the liquor at this spot with standard arsenic solution, and compare the test with that obtained in some other part of the dish.

Repeat the experiment with the basin floating in another basin of water. Heat the latter in the same way, and note the difference in behaviour. The pulp bleaches more evenly, owing to the even distribution of the heat by means of the water bath.

V. Laboratory Methods and Experiments.

Laboratory methods of bleaching wood pulp are sometimes regarded with suspicion, and the figures obtained accepted with reserve. The paper maker is apt to assume that the results so obtained are of little value for practical purposes; the objection being generally based upon the fact that in practice the amount of bleach required to treat a ton of pulp is higher, and that the yield of air-dry bleached pulp is often lower than that stated by the chemist.

In reference to the latter point, viz., as to the yield of air-dry bleached pulp obtained from one ton of the unbleached pulp as received, it is very probable that most paper makers have examined and tested the loss in weight which takes place. Some of this loss is due to the chemical reactions, and some of it to what would be called unavoidable mechanical losses. The loss in weight actually due to the use of the bleach is readily determined in the laboratory, and the mechanical losses may easily be measured in the mill itself.

The argument that the amount of bleach consumed in practical work is greater than the amount shown by the conditions which exist in the laboratory cannot be used as an excuse for ignoring the results of laboratory analysis. Indeed, quite the contrary, since the aim of the paper maker should be to bring the conditions of practical working into line with the laboratory methods in order to reduce the losses, subject of course, to a careful control of the costs of any modification. It is obvious that any alteration in procedure which affects the saving of, say, 1 per cent. or 2 per cent. in bleach, are of little value if the cost involved by the introduction of altered methods exceeds the value of the chemicals saved.

Apart from these practical and important considerations, the fact remains that the laboratory method must ultimately be referred to. The conditions under which the pulp is bleached are capable of exact and rigid control, so that the figures

obtained are strictly comparative, and capable of repetition by any chemist who examines the pulp under the same conditions.

It might be suggested that if a given pulp requires 10 per cent. of bleach, according to the laboratory method, and consumes 12 per cent. in practice before the pulp reaches the same standard of colour, another pulp which requires 25 per cent. in the laboratory would consume 30 per cent. in the mill. This is merely a supposition needing confirmation by reference to daily results obtained on a large scale. The difference might be merely an extra 2 per cent. as before.

The whole question seems to resolve itself into the possibility of adopting some standard method for determining the bleaching quality of a pulp which can be made use of in the laboratory, and accepted by paper makers as an indication of the value of the pulp in regard to bleaching. Bearing in mind that such results would be strictly comparative, it would then be necessary to ascertain the minimum quantity of bleaching powder consumed under conditions which approximate the general practice in the paper mill. These conditions have already been dealt with at some length. They can be classified under two heads :—

(A.) *Variable conditions easily applied.*
The temperature, density of bleach liquor; proportion of liquor to air-dry pulp.

(B.) *Variable conditions not always easy of application.*
Preliminary washing of pulp with water; use of caustic soda, and any system of double bleaching.

In devising a standard method for testing the bleaching qualities of a pulp only the conditions under heading (A.) could be taken into consideration. As a standard temperature it is not advisable to bleach with a mixture having a temperature greater than 100° F. The danger of over-bleaching and subsequent loss of colour is well known to paper makers and need not be discussed. The question of the amount of liquor added to the air-dry pulp is also an important one, for the proportion of water and bleach liquor per ton of air-dry pulp exercises considerable influence on the final results.

The thicker the mixture the greater the economy of bleach, but there must be enough liquid to ensure a proper circulation of the mass. The density of the solution used for bleaching is mainly determined by the proportion of solution used per ton of pulp. Whatever the density of the stock solution of bleach

sufficient water must be added, so that the actual strength of the bleach liquor mixed with the pulp does not matter so long as the actual volume is measured, the corresponding weight of powder being known.

Now these conditions are sufficient for instituting a standard method, and it should not be difficult to obtain accurate results.

The factors common to all systems of bleaching pulps, viz., those described as *variable conditions easily applied* may therefore be used as the basis of a standard laboratory method which would give comparable results for all pulps.

The mere percentage consumption of bleach is not the final solution of the question, as the colour of the resultant product is, and always must be, the paper maker's criterion of bleaching quality.

Approximate Method for determining Bleach Consumption.—The amount of bleaching powder required for a given weight of pulp can be determined to some extent without special appliances or chemicals, if a fairly sensitive balance and a few measuring vessels are available. The following rough method may be employed with advantage under ordinary conditions, although the results are not sufficiently accurate for the purpose of settling disputes. The method is given in the form of instructions :—

Weigh out 100 grams of the air-dry pulp. Tear up into small pieces and soak in a little warm water. Transfer the mass to a large bottle, add a few beads and sufficient water to cover. Shake the mass vigorously until the pulp is sufficiently broken up. Filter off the excess water into a measuring vessel and squeeze out the mass by hand, adding the liquid to the filtrate in the measuring vessel. Weigh out the 100 grams in 10 lots of equal weight and to each add one-tenth of the liquid so that each lot represents exactly 10 grams of the air-dry pulp together with the water used in disintegrating same. Place each lot in an ordinary tumbler and add various quantities of clear bleach liquor from mill stock so as to obtain what might be termed a progressive series of bleaching tests, thus :—

> If the mill stock has a density of 6° Tw. it may be assumed that one gallon of clear solution 6° Tw. contains 0·5 lbs. of good bleaching powder (100cc. of 6° Tw. liquor =5·0 grams. powder.

To the several lots of pulp add sufficient solution to give the varying percentages of dry bleaching powder as shown in the appended table:—

No.	Grams of air-dry pulp in mixture.	Percentage dry bleaching powder to be added.	Actual Wt. dry powder required. grams.	Volume of Bleach liquor to give the weight of powder stated.	Period required for exhaustion of bleach.
1	10·0	2·0	0·2	4·0 cc.	
2	10·0	4·0	0·4	8·0 cc.	
3	10·0	6·0	0·6	12·0 cc.	
4	10·0	8·0	0·8	16·0 cc.	
5	10·0	10·0	1·0	20·0 cc.	
6	10·0	12·0	1·2	24·0 cc.	
7	10·0	14·0	1·4	28·0 cc.	
8	10·0	16·0	1·6	32·0 cc.	
9	10·0	18·0	1·8	36·0 cc.	
10	10·0	20·0	2·0	40·0 cc.	

Stir the mixture vigorously and allow to stand at the ordinary temperature until the bleach in each case has been exhausted. Note the time required for complete exhaustion of the available chlorine and record the results in the last column of the table.

To test the solution as to the exhaustion of bleach use starch-iodide test papers which are coloured blue with a drop of the solution containing any traces of bleach unconsumed.

If it is necessary to obtain the results quickly place the tumblers in a large water bath and maintain the mixtures at a temperature of 100° Fah. In this case stir the mixtures at frequent intervals with a glass rod.

An experiment of this kind not only gives information as to the amount of bleaching powder required to produce a certain result in colour, but affords valuable information as to the rate of consumption. It may be noticed that in the case of a pulp which requires about 14 per cent. of bleaching powder the changes in colour between the tests marked 6 and 7 will be very slight. This process then is obviously a convenient one for determining the minimum amount of bleach required to give the maximum colour.

The experiments may be carried out with several modifications, such as variations in the temperature at which the operation is performed and variations in the proportion of water added.

Example.—In one experiment with soda pulp broken up in the manner described and bleached at 100° F. (40° C.) the results were :—

TABLE SHOWING TIME OF EXHAUSTION.

No.	Weight of pulp. Grams	Per cent. of dry bleach added.	No. of minutes for exhaustion of bleach.
1	2·0	4·0	20
2	2·0	8·0	30
3	2·0	12·0	45
4	2·0	16·0	80
5	2·0	20·0	130

The pulp reached a fair colour with a consumption of 16 per cent. bleach, the maximum being obtained with 20 per cent. Naturally, if the former colour is sufficiently white for the paper maker, it is possible to effect a considerable saving in bleach and time. It is not to be supposed that with a potcher full of pulp the soda wood will come up to a maximum colour in the time given. In many cases five to seven hours are required for a full bleach, and when the final colour obtained by the usual percentage of powder comes somewhat lower than is desired, it is a common practice to add a little further bleach and continue the operation. Such a method does not always succeed, since the pulp is associated with a large proportion of soluble organic compounds removed by the bleach originally added, so that no improvement results.

Titration Method.—The ordinary method of testing a pulp as to its bleaching qualities is based upon the principle of adding to the pulp broken up in any convenient form and mixed with a suitable quantity of distilled water, clear bleach solution containing an equivalent of dry bleaching powder in excess of that actually required to produce a maximum colour. The method is here given in the form of instruction.

Preparation of Bleach Liquor.—Weigh out about 60 grams of good bleaching powder into a large bottle and add 1,000 cc. of distilled water. Shake vigorously and filter. This proportion will give approximately a 5 per cent. solution. Measure the exact strength of this by means of a standard solution of arsenic.

Since good bleaching powder usually contains 35 per cent. to 36 per cent. of available chlorine assume the following relations:—

1 cc. N/10 arsenic = ·00355 grams chlorine.
(35·5 grams. chlorine = 100 grams good bleaching powder).
1 cc. N/10 arsenic = ·01 „ „ „ „

Having ascertained the number of cc. of arsenic required for 10 cc. of bleach solution dilute the latter until—

1 cc. of bleach solution = 5 cc. N/10 arsenic.
= ·05 grams good bleaching powder.
20 cc. „ „ = 1 gram. good bleaching powder.

It is not strictly necessary to make the solution 5 per cent. in strength, but these proportions are exceedingly useful when making a long series of experiments.

Example—

Bleaching powder	60 grams.
Water	1,000 cc.
Solution obtained	900 cc.

Found 1 cc. solution = 5·5 cc. N/10 arsenic.
1 cc. „ = 5·5 × ·01 grams good bleaching powder.
= ·055 grams good bleaching powder.
or 18·18 cc. solution = 1 gram good bleaching powder.

Water required to produce 5 per cent. solution = 1·82 cc. for 18·18 cc. bleach solution giving—

20 cc. solution = 1 gram good bleaching powder.

Preparation of Sample of Pulp.—Weigh out 10 grams of the air-dry pulp, macerate in a mortar with a small quantity of water, and finally transfer the completely disintegrated pulp into a tumbler or bottle with sufficient distilled water to give the following proportions:—

Air-dry pulp	10 grams.
Distilled water	250 „

From a burette run in some of the standard clear bleach solution to give an equivalent of bleaching powder in slight excess of that which the sample appears to require.

This is partly a matter of experience. In the case of an easy bleaching pulp a quantity of powder equivalent to 12 per cent. of the weight of air-dry pulp may be taken, and in the case of pulp requiring larger quantities the amount added may be 20–25 per cent.

Allow the mixture to stand for 10–12 hours with occasional shaking, and when the colour of the pulp has attained a maximum as judged by appearance, filter off the solution, squeezing the mass of pulp slightly between the fingers and washing with distilled water until every trace of excess of bleach has been removed, adding the washings to the filtrate.

Titration of filtrate for unconsumed bleach.—Determine the amount of unconsumed bleach still in the filtrate by titrating with standard arsenic, Deduct the amount so found from the quantity of bleach originally added and calculate the percentage of bleach consumed by the sample.

Bleaching at 100° *Fah.*—If the test is required quickly, keep the tumbler containing mixture of pulp and bleach in a water bath at a temperature of 100° F. (40° C.) stirring the mixture at frequent intervals. After three hours filter off and titrate the solution for any unconsumed bleach.

Repetition of the test.—If a considerable excess of bleach is found in the filtrate, repeat the test adding sufficient bleach to give only one or at the most two per cent excess.

Progressive method of Bleaching.—This method may be employed when it is necessary to determine exactly the *maximum* colour possible with a *minimum* percentage of bleaching powder, The approximate method has already been described and the following details are those required for a more exact analysis.

Weigh out 8 or ten lots of the pulp, each to contain exactly 10 grams. Macerate each lot separately in a mortar with a small quantity of distilled water taking care to see that the pulp is completely and uniformly broken up. Transfer the mass to a beaker washing out the mortar with small quantities of distilled water, until the total volume of water added is 250 cc. To the several lots of pulp add standardized bleach solution to give varying percentages of dry bleaching powder in a manner similar to that shown on page 102.

Bleaching at 100° *F.*—Place the tumblers in a water bath at 100° F. and stir each sample with a glass rod, noting the time at which the bleach is exhausted.

Bleaching Cold.—If preferred, allow the bleach solution in each case to exhaust at the ordinary temperature.

Comparison of Colour.—Make up the bleached pulp into small sheets, place them side by side and note the stage at which the colours of the bleached samples are alike. In this way determine which percentage of bleach gives a maximum colour.

Complete experiments carried out on the above lines are shown in chapter VI.

The Rate at which Bleach is Consumed.—As an illustration of the study of the rate of bleach exhaustion, the following experiments may be quoted, Three varieties of pulp were examined :—

(A) Brand C.—An ordinary soda wood pulp. 50 grammes air-dry pulp with 450 cc. bleach liquor at 65 degs. F. (containing bleach solution equivalent to 11·7 grammes of dry bleaching powder),

Brand B.—A sulphite pulp, About 14 per cent. of bleaching powder, calculated on the air-dry weight of pulp added. Actual consumption for colour required amounted to 12·5 per cent.

Brand A.—A sulphite wood of good colour, requiring a consumption of 8 per cent. of bleach.

Setting out in tabular form the rate at which the amount of dry bleaching powder is consumed, the following results are obtained, expressed in terms of the percentage rate. The total bleach added is taken as 100 and the proportions consumed each hour are taken as percentages of the total :—

RATE OF CONSUMPTION.

Hours.	Brand C.	Brand B.	Brand A.
0	·0	·0	·0
1	33·0	—	20·0
2	44·0	30·0	33·0
3	51·0	—	43·0
4	66·0	55·0	49·0
5	70·0	—	56·0
6	—	78·0	63
7	80·0	90·0	70

It will be noticed that in none of these cases was the total bleach consumed in the seven hours. If the figures are plotted out on a curve, the differences in behaviour become very clear.

Thus with Brand C., the pulp bleaches very rapidly during

the first hour, and then bleaches at a uniform rate for the succeeding four hours, and subsequently consumes bleach very slowly.

In the case of Brand B., the pulp bleaches somewhat rapidly during the first hour, and then the rate of consumption is quite uniform for the following six hours.

Finally with Brand A., the pulp, in common with most brands, consumes bleach rapidly at first, but afterwards the rate of consumption gets slower.

These three brands are typical of the conditions which will occur with the majority of pulps. The rate of consumption beyond the period of seven hours is not of immediate interest to the paper maker, but it is still a question of some moment in an investigation of this kind. The period for absolute and final disappearance of the total bleach added was not determined in these preliminary trials.

VI. The Question of a Standard Colour.

This subject has already received considerable attention in the pages of the *World's Paper Trade Review*, but the recent agitation amongst paper makers and others interested in the subject justifies further reference to the matter.

At a recent meeting of the Wood Pulp Association the question of having some standard method for testing pulps was thoroughly discussed and letters read from various analysts as to the possibility of arriving at some standard method. The consensus of opinion not only amongst the analysts, but also amongst the wood pulp agents and paper makers was that in view of the difficulty of obtaining or arriving at some standard of colour the question of a standard method was equally difficult.

From this it is evident that the question centres round the standard of colour rather than the absolute method. It would not be difficult to devise the conditions under which the pulp should be tested, but the comparison of the results obtained even when the method is carried out on certain approved lines would be of no value without careful reference to the ultimate colour of the bleached samples.

If colour was a quality of paper which permitted of accurate and ready measurement by simple appliances which could be used without special skill or knowledge the problem would be greatly simplified. But while such important qualities of paper, such as the weight, substance, strength, and similar physical properties, can easily be measured, the precise expression for colour involves considerable experience.

The quality of a paper in reference to its weight is usually expressed in terms of the weight in lbs. of a ream of 480, 500 or 516 sheets, and the reader can readily conjure up a mental picture of a ream having that weight, or of the sheet corresponding to the substance represented by that particular weight.

Without going into the theory of the measurement of colour and the instruments by which the colour is determined, it will be sufficient for the moment to state that since any colour is made up of the combination in varying proportions of the three primaries, yellow, red and blue, then the colour of any substance may be expressed in terms of the number of units of each of the primaries which, when combined, match the colour of the sample.

The colour of a certain paper may therefore be expressed, for example, as composed of ten units yellow, five units blue, three units red, and this record is a definite measurement of the colour. The instrument used for measuring colour in this way is the tintometer invented by Mr. J. W. Lovibond, an instrument now well known and applied in many industries for commercial purposes.

Colour of Samples.—Some experiments were carried out for the purpose of determining the variations which occur in the colour of the pulp when submitted to different conditions of bleaching. The bleached samples obtained were submitted to Mr. Lovibond, who carefully recorded the colours of the samples without knowing the conditions under which the samples were produced.

General Method of Procedure.—The experiments to be described were all carried out on strictly comparable lines in order to obtain samples which could be fairly compared with one another in regard to the final colour obtained. With each pulp selected for examination two series of experiments were made :—

Series 1.—Pulps bleached at a temperature of 100° F.

Series 2.—Pulps bleached at the ordinary temperature.

In each of the series some eight or ten lots of pulp cut from the sample sheet selected were carefully weighed out, equal quantities being taken in each case. The small lots so obtained were broken down in a mortar with a small quantity of water, transferred to a stoppered bottle and vigorously shaken until the sample was completely disintegrated and in a fit condition for bleaching. The contents of the bottle were then transferred to an ordinary tumbler, care being taken to use the same volume of distilled water for each sample, so that the conditions were absolutely alike in every case.

Varying quantities of clear bleach liquor were added to the several tumblers. For example, to the first tumbler bleach liquor containing bleach equivalent to 2 per cent. on the air-dry weight of the pulp was added; to the second an amount of bleach liquor containing bleach equivalent to 4 per cent. on the weight of air-dry pulp; to the third a quantity equivalent to 6 per cent. of bleach on the air-dry weight of the pulp; and so on throughout the whole series.

In Series 1 the whole of the tumblers were placed in a water bath and maintained at a temperature of 100° F., the contents of each tumbler being stirred occasionally with a glass rod. The mixtures were carefully watched and tested with starch iodide paper, and the time at which the bleach became exhausted was recorded. As soon as the bleach in each tumbler became exhausted the pulp was removed from the water bath and washed free from bleach residues.

When the bleach was exhausted in the whole of the samples comprised in the series, and these had been thoroughly washed with water, they were made up carefully on a hand mould so that finally a series of bleached sheets of equal thickness and substance was obtained.

The sheets were dried by exposure to air, and subsequently pressed between glazed pressing boards, in order to secure uniformity of thickness, texture and surface. The sheets in this condition were finally submitted to colour measurement.

In Series 2 the conditions of the experiment were exactly the same as regards the weight of pulp treated, the quantity of water used for the wet mixture, the proportion of bleach solution added, the only difference being that the samples were put aside, and the bleaching conducted at the ordinary temperature.

The samples were occasionally stirred and tested at intervals in order that the time at which the bleach became exhausted could be recorded. In this case the operation occupied a much longer time.

One of the main objects in carrying out the two series was to determine the effect of bleaching the pulps at a temperature of 100° Fah., instead of allowing them to bleach at the ordinary temperature.

Experiment 1. Bleaching at 100° F.—The pulp selected for the first experiment was a normal strong sulphite not ordinarily used as a bleaching pulp, but one which at the same time did not require more than 18 per cent. of bleach solution approximately to bring it to a good working colour.

The bleach solution was prepared and standardised in the following manner:—Forty grams of good bleaching powder were broken down and thoroughly shaken with 1,000 cc. of water. The solution was filtered and the clear liquid titrated with standard arsenic solution in order to determine the exact value of the bleach liquor.

Since 1 cc. of standard arsenic = ·00355 grams. chlorine and a good bleaching powder is supposed to contain 35 to 36 per cent. available chlorine, it is convenient to take the strength of the arsenic solution as—

1 cc. standard arsenic = ·00355 grams chlorine.
" " " = ·01 grams good bleaching powder.

The solution prepared as described after titration with arsenic showed—

1 cc. bleach liquor = 3·95 cc. standard arsenic.
" " " = 3·95 × ·01 grams. bleaching powder.
" " " = ·0395 grams. bleaching powder.
25·3 cc. = 1 gram. good bleaching powder.

For every one gram. of good bleaching powder required 25·3 cc. of the clear bleach solution was used.

Preparation of the Pulp Samples.

Twelve lots of the pulp were carefully weighed out, exactly three grams being taken for each lot. The samples were broken down with a small quantity of water, disintegrated completely and transferred to tumblers, the quantity of water used being 200 cc. in each case.

Process of Bleaching.

Series 1.—The requisite amounts of bleach solution equivalent to the required proportions of bleaching powder were added to each tumbler. The whole of the twelve samples were then placed in a water bath and heated at 100° F., being occasionally stirred until the bleach was exhausted. The time taken for the exhaustion of the bleach was noted.

The following table gives a record of these observations:—

TABLE OF RESULTS.

Bleaching effected at a temperature of 100° Fah. Three grams. of air-dry pulp taken for each test.

No.	Per cent. bleaching powder required.	Grams. bleaching powder to be added.	Bleach solution taken c.c.	No. of hours required to exhaust bleach.
1	2·0	·06	1·5	½
2	4·0	·12	3·0	½
3	6·0	·18	4·5	2¼
4	8·0	·24	6·0	5½
5	10·0	·30	7·6	8
6	12·0	·36	9·1	12
7	14·0	·42	10·6	16
8	16·0	·48	12·1	22
9	18·0	·54	13·7	28
10	20·0	·60	15·2	34
11	22·0	·66	16·7	41
12	24·0	·72	18·2	48

Experiment 2. Bleaching at 60 F.—In the second series of experiments the same pulp was employed, similar quantities were weighed out and similar amounts of bleach solution were used for the respective samples, the only difference being that the pulps were not heated but merely exposed at the ordinary temperature.

TABLE OF RESULTS.

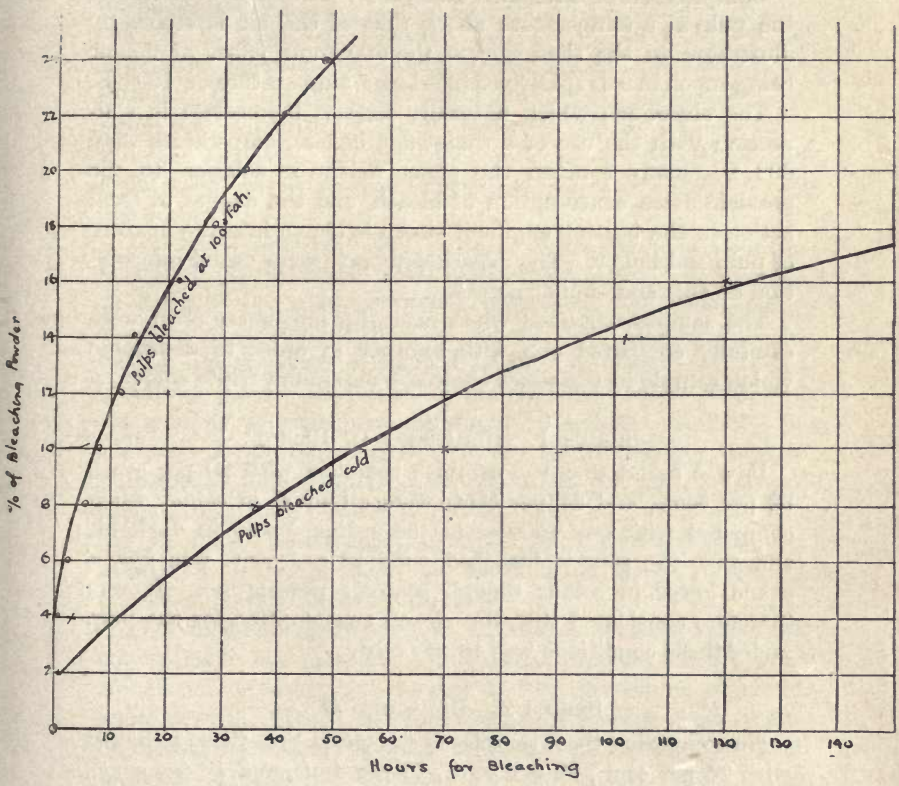
Bleaching effected at temperature of 60° Fah. (ordinary temperature of air). Three grams. of air-dry pulp taken for each test.

No.	Per cent. bleaching powder required.	Grams bleaching powder to be added.	Bleach solution taken c.c.	No. of hours required to exhaust bleaeh.
1	2·0	·06	1·5	½
2	4·0	·12	3·0	3½
3	6·0	·18	4·5	24
4	8·0	·24	6·0	36
5	10·0	·30	7·6	70
6	12·0	·36	9·1	—
7	14·0	·42	10·6	102
8	16·0	·48	12·1	120
9	18·0	.54	13·7	160
10	20·0	·60	15·2	164
11	22·0	·66	16·7	*
12	24·0	·72	18·2	*

* Stopped at 164 hours. Trace of bleach left in 22 per cent. sample, and 1 % of bleach left in 24 per cent. sample.

On comparing these two tables it will be seen at once that the time required to exhaust the bleach was much greater in the series where the process was carried out at the ordinary temperature.

The difference in behaviour is illustrated by the accompanying curve showing the relation between the time of exhaustion and the percentage of bleach in the solution.



The next point to be studied is the exact colour measurement for each of the pulps in the series.

The comparison between the colours of the samples bleached hot as compared with those bleached cold is also a matter of considerable importance.

VII. The Measurement of Colour.

Comparison of Bleached Samples.—The effect of bleaching the pulp at a temperature above that of the air is strikingly illustrated in the time curves, the maximum effect of colour being much more rapidly produced at a temperature of 100° F.

The objections which naturally suggest themselves in connection with the use of a somewhat higher temperature than 60° F. chiefly concern the paper maker in relation to the possible extra consumption of bleach, and the danger of local action in the beating engine if steam is blown into the mixture of pulp and liquor. The experiments give some useful information on this and similar points.

The samples obtained when made up into sheet form were carefully compared one with another in order to determine which sample in the series showed a maximum white colour.

Series 1.—Bleached at 100° F.

It was found that the samples bleached with 20 per cent., 22 per cent., and 24 per cent. were all equal in colour when compared with one another in the ordinary way in daylight, and that the sample bleached with 18 per cent. was just a shade lower in colour though scarcely perceptible. It was therefore considered that the bleach consumption for the pulp under these conditions was 18 per cent.

Series 2.—Bleached Cold.

On comparing these samples it was found that those bleached with 24 per cent., 22 per cent., 20 per cent., and 18 per cent., respectively, were for all practical purposes equal in colour, though it was just possible to discriminate between the 20 per cent. sample and the 18 per cent. sample. The consumption point for the series under these conditions was finally taken as being between 16 per cent. and 18 per cent. bleach.

These results would appear to indicate that under careful laboratory conditions the temperature had no effect upon the final result, except to hasten the process of bleaching. Taking 18 per cent. as representing the bleach consumption for this pulp the time required for bleaching cold was 160 hours, whereas by bleaching at 100° F. the period of time was only 28 hours; that is to say, instead of six days the pulp was properly bleached in one day with the same quantity of bleaching powder.

It is not suggested, however, that the methods outlined in the above experiments should be adopted as the definite or standard process for determining the bleach consumption of pulp, the object being to compare the results obtained by the two methods. But as a control of the method which has been described at various times by analysts the procedure is certainly useful.

The usual routine which is followed in testing a pulp for bleaching properties is to add clear bleach liquor to a weighed quantity of the pulp previously macerated, and mix with a suitable proportion of distilled water. The volume of clear bleach liquor added is such that the equivalent of active bleaching powder contained therein is somewhat in excess of the amount which experience would estimate as necessary for the pulp in question. That is to say to an ordinary sulphite pulp bleach liquor equivalent to about 20 per cent. or 25 per cent. of bleaching powder would be taken for the sample, and the amount of active chlorine unconsumed after the pulp had attained a maximum colour, the latter being merely judged by experience, would be determined.

The difficulty of arriving at a final conclusion as to the colour lies in the fact that the maximum colour of one pulp would not necessarily be equal to the maximum colour of another pulp. Hence the importance of having some means of measuring colour of what may be described as the final bleached sample.

The practice usually adopted by us has been to carry out the bleaching test in the following manner:—

(1) Add 25 per cent. of bleaching powder to the suitably prepared sample. When the maximum colour has apparently been reached, determine the amount of bleaching powder still unconsumed.

(2) To a fresh sample of pulp add a slight excess above the amount of bleach shown by the above test. Allow the bleach to exhaust and make up the bleached pulp into a small sheet.

(3) To a fresh sample of the pulp add 2 per cent. less bleach than that used in Experiment 2. When the bleach is exhausted make up the sample into a small sheet as before. The colour in this case will be lower than that obtained in Experiment 2.

(4) Attach the two samples obtained in Experiments 2 and 3 to the report.

EXAMPLE.

Experiment 1.—Added 25 per cent. of bleach, found 23 per cent. unconsumed, giving 12 per cent. as the bleach consumption.

Experiment 2.—To a fresh quantity of pulp added 12½ per cent. bleach. When the bleach was exhausted made up the pulp into small sample sheet.

Experiment 3.—To a fresh quantity of pulp added 10 per cent. bleach. Made the bleached pulp into a sheet as before, noting the fact that the colour was inferior to that of Experiment 2.

Experiments on an Easy Bleaching Pulp.—The experiments above recorded as applied to a hard sulphite pulp not originally intended to be used as an ordinary bleaching pulp were repeated on a well-known brand of sulphite pulp specially prepared as an easy-bleaching pulp.

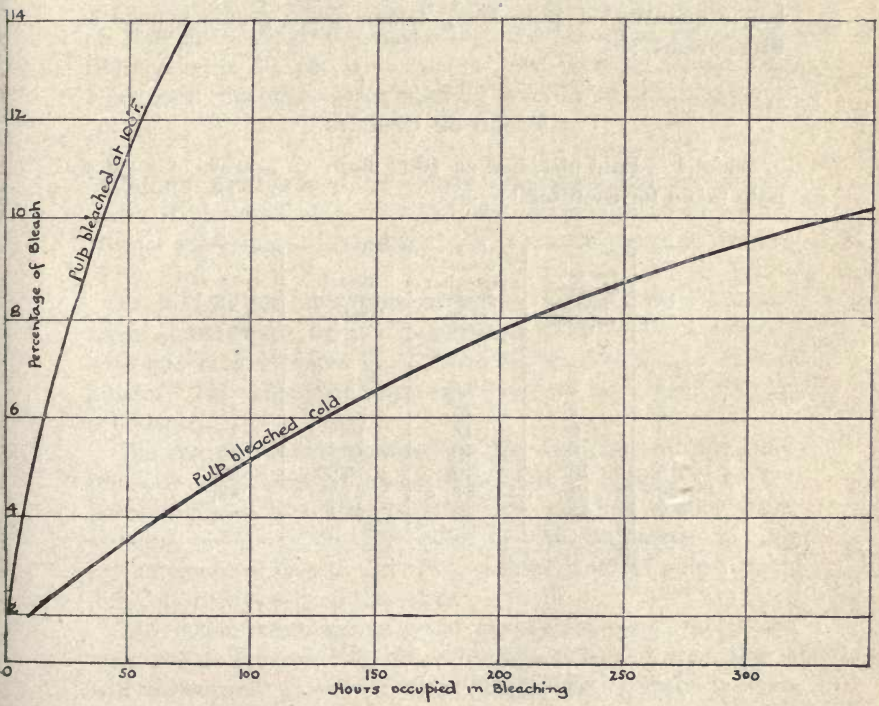
The conditions of the experiment were exactly the same, one series of samples being bleached at 100° F., and a second series being bleached at the ordinary temperature.

Although colour readings may not convey much information to the reader unfamiliar with the tintometer and the standard glasses used, yet they can be studied in conjunction with the practical methods of comparison usually employed. In regard to the latter it may be noted that the gradual improvement in colour with the pulps bleached at 100° F. and those bleached cold was the same; equal percentages of bleaching powder producing the same effect in both cases.

Comparing Colours by Observation.—The samples in each series were easily arranged in order of merit as to colour from 2 per cent. of bleach up to 18 per cent. of bleach, at which point, however, it was practically impossible to determine the order of merit of the samples bleached with 20 per cent., 22 per cent., 24 per cent. The samples were handed to several independent observers, who were readily able to arrange them in order of colour up to 18 per cent., but the results beyond this were variable.

This practical method of comparison showed that the bleach consumption could be taken as being 18 per cent., though in the case of the pulp bleached cold some point midway between the 16 per cent. and the 18 per cent. would be more exact.

It is evident that the further additions of bleach had no effect on the colour and the experiments carried out in this way determine with exactitude the minimum consumption of bleaching powder.



These facts are also brought out very clearly in the curves, for it will be noticed that the black line in the colour curves rapidly falls from 2 per cent. bleach down to 12 per cent. bleach, the fall being considerably less than 12 per cent. down to 18 per cent., corresponding with a slighter difference in the whiteness of the samples obtained between 12 per cent. and 18 per cent. At 18 per cent. for all practical purposes the curves ceases to fall, showing that the maximum colour has been reached.

Further Experiments.—Experiments similar to those already described were carried out with a normal easy bleaching pulp, usually calculated to require 8 per cent. to 10 per cent. of bleaching powder.

The methods of operating were exactly the same as those employed in the case of the 18 per cent. sulphite pulp and the results obtained are given in the following tables (a somewhat larger quantity of pulp being taken, seven grams instead of three grams) :—

TABLE OF RESULTS.

Series 1.—Pulp bleached at 100° Fah. (7 grams. of air-dry pulp taken for each test) :—

No.	Per cent, bleaching powder required.	Grams. bleaching powder to be added.	Bleach solution taken cc.	No. of hours required to exhaust bleach.
1	2	·14	3·6	1½
2	4	·28	7·2	7
3	6	·42	10·8	15
4	8	·56	14·4	25
5	10	·70	18·05	36
6	12	·84	21·75	48
7	14	·98	25·3	80

Series 2.—Pulp bleached cold (7 grams. of air-dry pulp taken for each test):—

No.	Per cent. bleaching powder required.	Grams bleaching powder to be added.	Bleach solution taken cc.	No. of hours required to exhaust bleach.
1	2	·14	3·6	17
2	4	·28	7·2	30
3	6	·42	10·8	144
4	8	·56	14·4	264
5	10	·70	18·05	336
6	12	·84	21·75	437
7	14	·98	25.3	504

The samples on being compared with one another were easily arranged in order of colour up to the point at which 10 per cent. of bleach had been consumed. It was found that the samples bleached with 10 per cent., 12 per cent., 14 per cent., were all equal in colour in both series, namely in those bleached at 100° F. and those bleached cold. The maximum colour was reached with 10 per cent. and a good working colour with 8 per cent., the latter being slightly inferior to the maximum colour.

Colour Analysis.—The colour readings obtained for the series of bleached pulps in which the percentages of bleaching powder used ranged from 2 per cent. up to 24 per cent. are full of interest.

These readings have been carried out at the Colour Laboratories at Salisbury, by kind permission of Mr. J. W. Lovibond, who has himself taken great personal interest in the experiments. The colour readings can therefore be accepted with confidence.

The samples were examined by Mr. Lovibond without any previous knowledge as to the condition of bleaching or the percentages of bleaching powder used, and the results are a striking testimony to the value of the tintometer in the measurement of colour, even for readings of white pulps which differ so little one from the other.

The colour readings as given in the following tables are arranged in the order of the percentage of bleach used, and it will be noticed at once that although the operator had no

knowledge of the percentages, yet the colour readings arranged themselves almost precisely in the same order as the percentages of bleach.

COLOUR ANALYSIS.

For Pulp Bleached at 100° *F.*

Percentage of Bleach used.	Matching Standards.			Colour Developed.		
	Red.	Yellow.	Blue.	Black.	Orange.	Yellow.
2	·64	·88	·46	·46	·18	·24
4	·64	1·00	·28	·28	·36	·36
6	·48	·84	·19	·19	·29	·36
8	·16	·56	·09	·09	·07	·40
10	·13	·52	·09	·09	·04	·39
12	·13	·50	·09	·09	·04	·37
14	·11	·42	·06	·06	·05	·31
16	·11	·38	·06	·06	·05	·27
18	·04	·32	·10	04	·06*	·22
20	·04	·26	·04	·04	—	·22
22	·03	·24	·03	·03	—	·21
24	—	·20	·04	—	·04*	·16

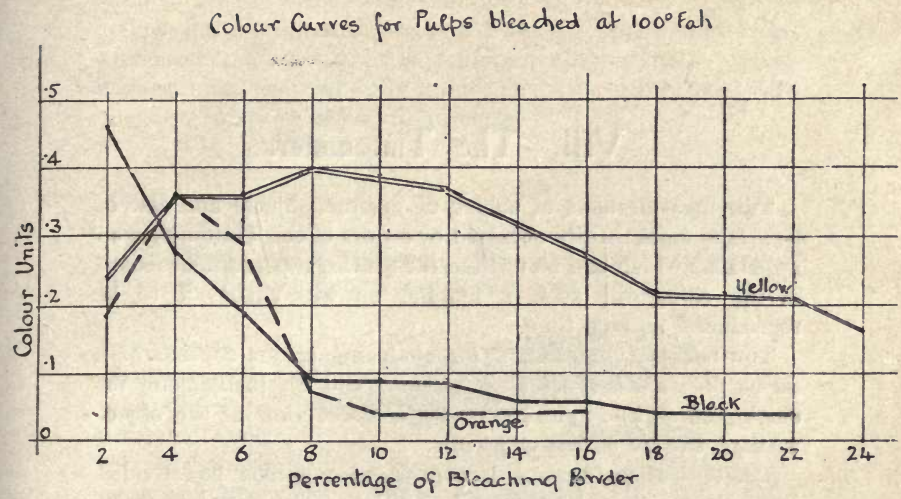
*Green.

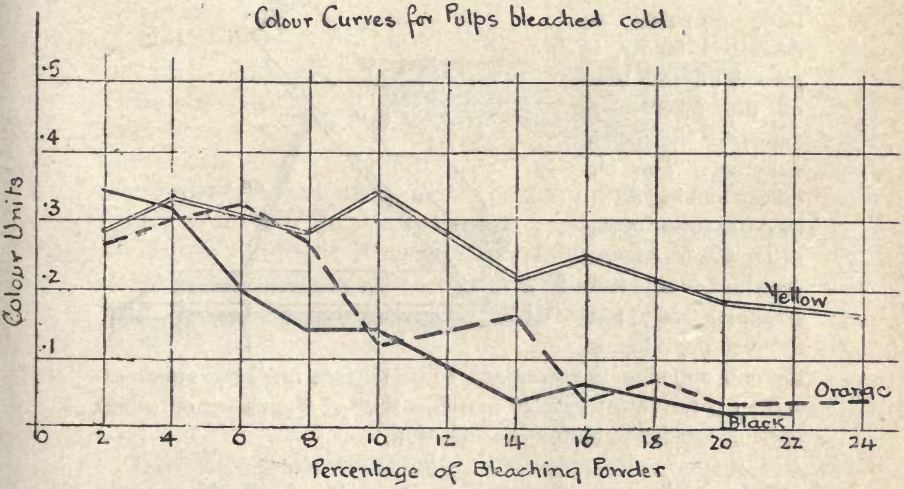
COLOUR ANALYSIS.

For Pulp Bleached Cold.

Percentage of Bleach used.	Matching Standards.			Colour Developed.		
	Red.	Yellow.	Blue.	Black.	Orange.	Yellow.
2	·60	·88	·34	·34	·26	·28
4	·62	·95	·32	·32	·30	·33
6	·52	·82	·20	·20	·32	·30
8	·40	·68	·14	·14	.26	·28
10	·26	·60	·14	·14	·12	·34
12	·22	·50	·08	·08	·14	·28
14	·19	·40	·03	·03	·16	·21
16	·11	·36	·07	·07	·04	·25
18	·07	·28	—	—	·07	·21
29	·06	·24	·02	·02	·04	·18
22	·07	·24	·03	·03	·04	·17
24	·04	·20	—	—	·04	·16

The amount of colouring matter, as represented by the standard glasses, red, yellow, and blue, decreases uniformly throughout the series.


Colour Curves for Pulps bleached at 100° Fah
Colour Units
·5
·4
·3
·2
·1
0
2
4
6
8
10
12
14
16
18
20
22
24
Yellow
Black
Orange
Percentage of Bleaching Powder

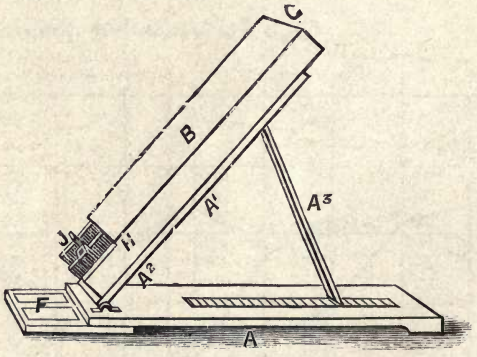

Colour Curves for Pulps bleached cold
Colour Units
·5
·4
·3
·2
·1
0
2
4
6
8
10
12
14
16
18
20
22
24
Yellow
Orange
Black
Percentage of Bleaching Powder

VIII. The Tintometer.

THE measurement of colour of opaque objects and also of liquids is most readily obtained by means of the Tintometer, an apparatus which can be utilised for making a permanent record of the colour in such a manner as will enable it to be reproduced at any time.

The necessary appliances for analysing colour consists of a series of standard coloured glasses, and an instrument for cutting off all side light and giving a direct view of the object without the aid of lens or prisms.

The optical instrument B consists of a narrow box divided into two chambers by a central partition. The apparatus may be inclined at any angle to suit the convenience of the operator. The opaque substance to be measured is placed on the base of the instrument at F opposite one of the chambers, while a standard white surface, prepared as described below, is placed on the base of the instrument opposite the other chamber. The observer looking down into the tubes of the instrument inserts standard coloured glasses in the grooves provided at the end opposite the standard white surface until the apparent colour of the latter exactly matches that of the paper or other opaque substance under examination.

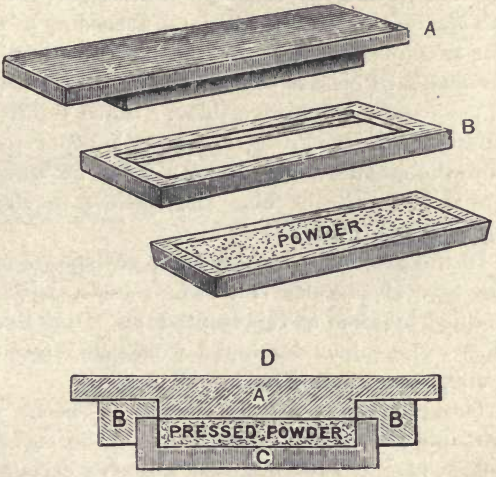


Colour Glasses.—The colours chosen for standards are red, yellow and blue, from which three colours any combination of

orange, green or violet can be obtained, and also any degree of neutral tint or black. Thus 5 units of red plus 5 units of yellow plus 5 units of blue absorb 5 units of white light which produces a neutral tint of a definite quality or shade. These glasses have been carefully standardised by comparison with chemical solutions of known strength.

Standard white surface.—Pure precipitated sulphate of lime pressed evenly into a tray is used for this purpose.

A represents two pieces of glass, one larger than the other, cemented together, the smaller piece just fitting into B, which is a rectangular frame $\frac{1}{10}$th of an inch deep; this fitting to a tray C, also $\frac{1}{10}$th of an inch deep. These are fitted together, then filled with the standard white, and struck evenly off; the powder is pressed lightly down with the small side of the glass presser in order to remove the frame B more easily from the tray C. The broad side of the presser is used to compress the powder even with the sides of the tray. The whole arrangement is shown in section at D.



The following colour readings for certain familiar objects and papers will afford some indication of the value or meaning of the colour standards:—

	Standard Glasses used to match colour.		
	Red.	Yellow.	Blue.
Prussian Blue Powder... ...	9·0	1·0	6·8
White Lead	·08	1·5	·2
Post Office Telegram Envelope	4·0	2·6	·5
Post Office Telegram Form ...	·5	·4	—
Westminster Gazette	—	·56	·56
Sphere	·02	·2	—
Ordinary Newspaper	—	·3	·1
Unbleached Sulphite Pulp ...	·44	·6	·28
Bleached Sulphite Pulp ...	·03	·24	·03

The colours of the samples having been matched in the instrument and the readings obtained for the standard glasses, the results can then be tabulated according to the actual colours. For example, in the case of the "Westminster Gazette" paper the standard glasses required to match the colour are ·56 units of yellow and ·56 units of blue. Since yellow and blue in combination produce green, the actual colour reading as distinct from the standard glasses would be ·56 units green, since the number of units of blue and yellow required to match the original colour are equal.

In the same way the ordinary newspaper examined amongst the several samples is a white paper with a yellowish tint inclined to green as represented by ·3 units yellow and ·1 units blue. The colour developed would therefore be represented by ·1 units green and ·2 units yellow.

The tabulation of the results is based upon the simple principle that three equal units of the standard glasses, red, yellow, blue, if superimposed, absorb a certain amount of light, or, in other words, produce a neutral tint. When, therefore, all three glasses are used in the measurement of a colour the smallest unit of them would be recorded as black.

In the case of the Prussian blue powder the smallest unit is 1·0 yellow. Hence this would be recorded as black, leaving 8·0 red and 5·8 blue. But blue and red together make violet, and the excess of red, namely, 5·8 would be registered as violet, and the excess of red, viz., $8 - 5{\cdot}8 = 2{\cdot}2$ recorded as red.

The colour sensations would therefore be described as reddish violet in which violet was the predominant colour. On this simple principle the colour sensations can be recorded as follows:—

TABLE OF COLOUR SENSATIONS BASED ON STANDARD GLASSES USED.

Substance examined.	Visual Colour. Black.	Red.	Violet.
Prussian Blue Powder... ...	1·0	2.2	5·8
		Green.	Yellow.
White Lead	.08	·12	1·3
		Red.	Orange.
Post Office Telegram Envelope	·50	1·4	2·1
		Red.	Orange.
Post Office Telegram Form ...	—	·10	·40
		Green.	
Westminster Gazette	—	·56	—
		Orange.	Yellow.
Sphere	—	·02	·18
		Green.	Yellow.
Ordinary Newspaper	—	·10	·20
		Orange.	Yellow.
Unbleached Sulphite Pulp ...	·28	·16	·16
		Yellow.	
Bleached Sulphite Pulp ...	·03	·21	—

The order in which the visual colours are recorded is:—In the first column the number of units of black, or in some cases excess of light are written; in the second column the diluent or adulterant colour; and, finally, the dominant colour.

IX. Standard Methods of Testing.

A Standard Method for estimating Bleaching qualities in Wood Pulp.—A careful study of the laboratory methods of testing and of the special experiments recorded in the previous chapters would indicate that it should be possible to devise some standard method for estimating the bleaching qualities of wood pulp which would be acceptable to the manufacturers and users of wood pulp. The following scheme is therefore put forward as a suggestion for the basis of such a test:—

Selection of samples from bulk.—Take 2 per cent. of the number of bales forming the consignment of pulp. From each of these selected bales draw one sheet. Cut the sheets in half so that buyer and seller may have duplicate samples.

Selection of Laboratory test samples.—Cut small strips $\frac{1}{4}$ inch wide and any convenient length of about 2 or 3 inches from each of the sheets in the bulk sample.

Weigh out 5 grams of air-dry pulp, taking equal lengths of the small strips so as to secure a representative sample.

Preparation of bleach liquor.—Assume that a good bleaching powder contains 35·5 per cent. available chlorine. This is a convenient figure because the decinormal solution of arsenic used has the following strength:—

100 cc. arsenic solution = ·355 grams chlorine.
= 1·0 gram bleaching powder.

Dissolve about 50-60 grams bleaching powder in 1,000 cc. water. Shake vigorously and filter. This gives a 5 per cent. solution. Titrate the clear bleach solution with decinormal arsenic and ascertain the number of cc. of bleach equivalent to 1 gram. of good bleaching powder.

[*See page* 104 *for details.*]

Preparation of test samples.—Macerate the 5 grams. of pulp in a mortar with small quantities of water, using about 50 cc. Put the mixture in a bottle.

Bleaching.—Calculate the number of cc. of bleach containing powder equivalent to about 20 per cent.* of the weight of the wood taken for experiment. Add this to the mixture in the beaker and finally add sufficiently distilled water so that the total volume of liquor is 125 cc. for every 5 grams. of air-dry pulp. Shake the mixture occasionally, and when the colour has attained its maximum, filter off the solution and wash the pulp thoroughly until the whole of the unconsumed bleach has been removed. This can be tested with starch iodide paper.

* *For further explanations, see page* 111.

Temperature for Bleaching.—Bleach at the ordinary temperature for preference. If desirable, bleach at 100° F. See page 101.

Titration of filtrate.—Determine the amount of unconsumed bleach in the filtrate by means of decinormal arsenic solution. Calculate the amount of powder actually used for the bleaching of the pulp.

Checking the results.—If the amount of bleach originally added proves to be much in excess of that actually consumed, carry out a second test, using bleach liquor in slight excess of the equivalent of bleaching powder as determined by the first experiment.

Sample sheets of bleached pulp.—By means of a small hand mould make up a few sheets from the bleached pulp in order to have a record of the colour produced under the conditions of the experiment. Attach these sheets together with a piece of the original pulp to the certificate.

Varying percentages of bleaching powder.—If desirable repeat the experiments, using varying percentages of bleaching powder, allowing the whole of the bleach to be consumed. Make up the bleached pulp after washing into sample sheets, marking each sheet with the percentage of powder required to give the colour reprented by the sample.

For description of this progressive method of bleaching, see page 105.

A standard for colour.—The pure standard of white which is used in most measurements for purity of colour is obtained by means of pure precipitated sulphate of lime. With Lovibond's Tintometer, an instrument for the measurement of colour, the white surface is prepared by measuring out a definite volume of pure sulphate of lime powder into a little tray. The surface of the powder is then carefully smoothed off with a piece of glass. The surface then closely resembles a sheet of paper with a matt finish.

The deviation of the bleached sample of pulp from this pure standard can be measured by means of the tintometer.

APPENDIX.

I. The Chemistry of Bleaching Powder.

In a book of this kind we do not propose to go into the many theoretical considerations advanced as to the probable constitution of bleaching powder, for the experimental difficulties necessary to prove the formation of the complex compounds, together with their complicated decomposition products, still render the subject one of a more or less indeterminate character.

Suffice it to mention that with all its imperfections, the constitutional formula, as advanced by Odling, for bleaching powder, and subsequently agreed upon by Lunge and other workers as a result of their investigations, seems to bear the closest approximation to the actual facts.

According to Odling, the electro positive element, calcium, is combined with the electro negative elements, oxygen and chlorine, as $Ca<^{+}_{\overline{OCl}}{}^{\overline{Cl}}$ and like all compounds where there is a preponderating influence of ionic conditions, in this case electro negative, so there is the corresponding tendency to decomposition under influences of moisture and heat.

It is a well-known fact that the best qualities of bleaching powder contain only 36 to 37 per cent. of active chlorine, a number much below the theoretical value, namely, 48·97 per cent.; that is, if the above formula be correct, and if the reaction of slaked lime and chlorine takes place as follows:—

$$Ca(OH)_2 + Cl_2 = Ca<^{Cl}_{OCl}\ H_2O.$$

This points to the incompleteness of the reaction and as a consequence an excess of base. This has been proved to be the case in practice, and many explanations have been advanced to

account for this anomaly. It has frequently been suggested that the basicity of the compound is due to the occlusion of particles of caustic lime by the chlorinated compound. A more reasonable explanation, however, is that the reaction is a reversible one.

$$Ca(OH)_2 + Cl_2 \rightleftharpoons Ca{<}^{Cl}_{OCl}\,H_2O.$$

Commercial bleaching powder, prepared by passing a current of chlorine gas over dry slaked lime, the latter usually being conveyed by a mechanical system in such a way that the lime and chlorine are moving in opposite directions, is a dry white powder when fresh, smelling strongly, especially when exposed to sunlight, of chlorine and oxygen compounds of chlorine.

On exposure to air decomposition takes place with absorption of moisture, the main products being calcium hypochlorite and calcium chloride; the decomposition is greatly expedited when the air is saturated with carbonic acid owing to the action of the latter upon the hypochlorite with the formation of hypochlorous acid.

$$Ca{<}^{OCl}_{OCl} + H_2CO_3 = CaCO_3 + 2\,HClO.$$

The value of bleaching powder to the paper maker essentially depends upon the percentage of active chlorine, together with its freedom from, grit, dirt, and any metallic particles.

Pattinson gives the following composition of commercial bleaching powder:—

Available Chlorine	36·00	per cent.
Chlorine as Chloride	0·32	,,
Chlorine as Chlorate	0·26	,,
Lime. CaO	44·66	,,
Magnesia. MgO	0·43	,,
Silica. SiO_2	0·50	,,
Carbonic Acid. CO_2	0·48	,,
Oxides of Iron and Alumina. F_2O_3 and Al_2O_3	0·35	,,
Moisture. Combined and Free	17·00	,,
	100·00	,,

On the basis therefore that 48·97 per cent. of active chlorine should be the true value for bleaching powder, a powder of the above composition would be approximately as under:—

Calcium Chloro Hypochlorite $Ca<^{OCl}_{Cl}$ ...	73·52 per cent.
Calcium Hydrate	21·16 ,,
Magnesium Chloride	0·50 ,,
Magnesium and Calcium Carbonates. $MgCO_3$ and $CaCO_3$	1·01 ,,
Other impurities in the Lime as above ...	1·09 ,,
Water excess	2·72 ,,

The constituents given show that in a normal bleaching powder containing 36 per cent, of active chlorine 73·5 per cent. of the true hydrated bleaching powder compound is present. The remainder consists mainly of caustic lime, together with the impurities contained in the lime, and a trace of calcium chloride and chlorate. The extent to which the last two constituents are present is a very important matter, inasmuch as these indicate the conditions obtained in the manufacture, while at the same time, it may be noted, the chlorate is perfectly useless for bleaching purposes under the ordinary methods of working in a paper mill.

Just as in the case of the alkaline hypochlorites as represented by soda we have the following decomposition under the influence of temperature: $3\ NaClO = NaClO_3 + 2\ NaCl$, so in the calcium chloro-hypochlorite compound under the same conditions, decomposition takes place as under:—

$$6\left(Ca<^{Cl}_{OCl}\right) = 5\ CaCl_2 + Ca\ (ClO_3)_2.$$

In a complete analysis of bleaching powder the following examination should be carried out:—

Proximate Analysis.

Determination of wood present in the bleach.—Weigh out 100 grams., or any other known quantity, and pass the powder through a 60 mesh sieve. The powder, if fairly dry, will go through this mesh easily, leaving the wood which can then be weighed. If the bleaching powder is in a moist condition it can be triturated with water in a mortar and passed through the sieve.

Sand and Grit.—To 10 grams. of the powder add water and hyhrochloric acid, warm until all the lime salts are decomposed and pass into solution; dilute with water, pour off the supernatant liquid, again dilute with water, filter, wash, dry and ignite the residue.

Chemical Analysis.

Determination of Bases and Silica.—Decompose 2 grams. of bleach with hydrochloric acid and sufficient hydrogen peroxide to reduce the oxygen compounds of chlorine. The amount of hydrogen peroxide that must be added can be readily determined, and the theory of the reaction is as follows:—

Bleaching powder when dissolved in water splits up into the following:

$$2\,Ca\!<\!\begin{matrix}OCl\\Cl\end{matrix}\,H_2O = Ca\!<\!\begin{matrix}OCl\\OCl\end{matrix} + CaCl_2 + 2H_2O.$$

When sulphuric acid is added to the solution of bleach

$$Ca\!<\!\begin{matrix}OCl\\OCl\end{matrix} + CaCl_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + 2Cl_2,$$

or if hydrochloric acid be used the same amount of chlorine is liberated.

$$Ca\!<\!\begin{matrix}OCl\\OCl\end{matrix} + CaCl_2 + 4HCl = 2CaCl_2\,2H_2O + 2Cl_2,$$

i.e., two molecules of chlorine are evolved in an aqueous solution as above.

Owing to the great affiinity of electro negative chlorine for electro positive hydrogen, the hydrogen elements in water are withdrawn from combination with oxygen, which latter is liberated in the atomic condition:

$$\overset{-}{Cl_2} + 2\overset{+}{H}.\overset{-}{O}H = 2H\overset{+}{C}l + \overset{+}{H}.O\overset{-}{H} + \overset{-}{O}.$$

If now hydrogen peroxide be added to the acid solution oxygen is evolved

$$H_2O_2 = \overset{+-}{H}O\overset{-}{H} + \overset{-}{O}$$

both atomic oxygens combine to form molecular oxygen which has no oxidizing action.

Hence where two compounds which singly are equally capable of doing work in bleaching, combine together to form molecular oxygen it is said to be an instance of mutual reduction.

Twenty volumes of hydrogen peroxide will when decomposed into water and oxygen furnish twenty times the original volume of peroxide taken.

1 cc. of H_2O_2 = 20 cc. of oxygen.
= 20 × 0·0014336 grams. oxygen at 0° C. and 760 mm. pressure.
= 0·028672 grams. oxygen.

On the assumption that bleaching powder contains about 36 per cent. active chlorine, the 2 grams taken for the analysis will be equivalent to

$$\frac{2 \times 36}{100} = 0{\cdot}72 \text{ grams. chlorine.}$$

$2Cl_2 = O_2$, *i.e.*, 142 parts by weight of chlorine
= 32 parts by weight of oxygen.

∴ 0·72 chlorine = 0·1622 oxygen.
= 5·65 cc. of 20 volumes hydrogen peroxide.

Excess of hydrogen peroxide can be added as it is easily decomposed on heating.

After reduction the solution can be made up to a definite volume and an aliquot part taken for the determination of silica, alumina and iron, lime and magnesia.

Determination of Available Chlorine.—When only the hypochlorite is to be determined, the following method of Penot's is both expeditious and accurate; it depends upon the direct oxidizing action of a hypochlorite upon sodium arsenite whereby the latter is converted into sodium arsenate, the oxygen being furnished by the hypochlorite of lime.

$$Ca{<}\begin{matrix}OCl\\OCl\end{matrix} = Ca{<}\begin{matrix}Cl\\Cl\end{matrix} + O_2$$

$$Na_2O.As_2O_3 + O_2 = Na_2O.As_2O_5.$$

For the determination of the chlorine 35·5 grams. of bleaching powder are weighed out from a well mixed sample and triturated up in a mortar, adding small quantities of water at a time and grinding thoroughly after each addition. In this way the bleach swells up to a voluminous paste without any dense particles and permits of greater accuracy in subsequent work. 100 cc. of water are added, and after mixing allowed to settle. The supernatant liquid is then poured off and fresh water again added until the whole of the bleach is transferred to a half litre flask which can then be made up to the mark, Shake the

flask vigourously and pour off 50 cc. of the bleach and titrate with a decinormal solution of arsenious acid, dissolved in sodium carbonate. The total number of ccs. consumed gives the percentage of active chlorine directly in the sample. It is as well towards the end of the reaction to allow the arsenious acid to drop slowly from the burette into the flask or dish containing the bleach solution, and after each addition of a few drops of arsenious acid, to test the solution with starch iodide paper. If active chlorine is still present the potassium iodide is decomposed, liberating free iodine, which immediately combines with the starch to form the blue iodide of starch. The end point is obviously therefore the point at which there is no colour. It is seen that this method will not differentiate between an accurate end point and excess of arsenious acid. It is advisable therefore to repeat the operations, running in a quantity of arsenious acid with one or two ccs. of the number previously obtained.

1 cc. of decinormal arsenious acid = 0·00495 grms. As_2O_3.
= 0·00355 „ chlorine.

Estimation of Chlorates.—The determination of the salts of chloric acid can be readily made by the method of Fresenius, in which use is made of the oxidizing action of hypochlorites upon lead acetate whereby the latter is converted into peroxide of lead, whilst the chlorate is unaffected. The process is as follows:—

A known quantity of bleaching powder, say 2 grams., are triturated with water and a solution of lead acetate added in excess. At first a precipitation of lead chloride and hydroxide takes place as is seen by the white colour, but this rapidly turns yellow and finally brown by direct oxidation to the insoluble lead peroxide PbO_2 whilst chlorine is evolved. The mixture should be frequently stirred briskly or shaken, and after standing about eight hours the lead peroxide can be filtered off from the chlorate.

The excess of lead and lime salts are removed as carbonates by the addition of sodium carbonate and filtering. The residue is washed until free from acid, and the washings, after evaporating nearly to dryness, added to the original filtrate. The solution of sodium chlorate is then decomposed by heating in a round bottom flask with concentrated hydrochloric acid,

to which a little magnesite has been added. The magnesite is acted upon slowly by the acids and thus prevents a rush back of liquor in the tubes when decomposition is completed.

The reaction is as follows :—

$$NaClO_3 + 6HCl = NaCl + 3H_2O + 3Cl_2.$$

The chlorine is collected in a couple of U shaped bulbs joined up in series containing a solution of potassium iodide. The latter is decomposed, iodine being liberated and potassium chloride formed.

$$2KI + Cl_2 = 2KCl + I_2.$$

The iodine can be determined by a decinormal solution of sodium thiosulphate, adding a solution of starch as indicator, the end point being taken when the solution first becomes colourless.

$$2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI.$$

$$\text{Since } Na_2S_2O_3 = I = Cl = \frac{NaCl_3}{6} = \frac{Ca(ClO_3)_2}{12}$$

therefore 1 cc. of N/10 thiosulphate = 0·0248 grams.

$$Na_2S_2O_3 5H_2O.$$

$$= 0{\cdot}01725 \text{ grams. } Ca(ClO_3)_2.$$

Estimation of Chlorides.—The chlorides present as such in bleaching powder can be determined by the difference between the chlorine after reduction of hypochlorite by means of hydrogen peroxide in the basic solution and the active chlorine.

A definite quantity of bleaching powder is ground up with water, the equivalent quantity or excess of hydrogen peroxide added, shaken, made up to a known volume, and filtered. An aliquot part is taken, acidified with pure nitric acid, and then brought back to the neutral or very slightly alkaline condition with pure sodium carbonate. The solution may then be titrated directly with decinormal silver nitrate.

$$1 \text{ cc. of which} = 0{\cdot}017 \text{ grams. } AgNO_3.$$

$$= 0{\cdot}00355 \text{ grams. chlorine.}$$

Carnot's Method for Analysis of Chlorine, Chlorates, and Chlorides.—A method devised by A Carnot, Comp. Rend 122.445, for determining the percentage of active chlorine, chlorates and chlorides is worth mentioning in that the opera-

tions are fairly simple to carry out, and it has, moreover, the advantage that the various compounds of chlorine can be determined directly upon one solution.

The available Chlorine is first determined by standard arsenious acid (Penot method).

(2) **Chlorates.**—The liquid is then slightly acidified with sulphuric acid and a quantity of ammonium ferrous sulphate added equivalent to about 20 times as much as the calcium chlorate supposed to be present. Then heat the liquid to boiling, adding in small successive quantities 5 ccs. of sulphuric acid diluted with 15 ccs. of water. After stopping up the vessel cool and titrate back the excess of ferrous ammonium sulphate with decinormal potassium permanganate.

$$1 \text{ cc.} \frac{N}{10} KMnO_4 = 0{\cdot}316 \text{ grams. } K\,MnO_4.$$
$$= 0{\cdot}072 \quad ,, \quad FeO.$$
$$= 0{\cdot}01775 \quad ,, \quad NaClO_3.$$

Since,

$$NaClO_3 + 6FeO = NaCl + 3Fe_2O_3.$$

(3) **The Total Chlorides,**—The slight pink colour produced by potassium permanganate is removed by the addition of a tiny crystal of ferrous sulphate, and subsequently a definite amount of decinormal silver nitrate is added. Make up to a known bulk, filter off the silver chloride and titrate back the excess of silver nitrate by means of a decinormal solution of potassium thiocyanate. The iron present in the solution serves as an indicator when an excess of potassium thiocyanate is added beyond the end point.

The Author maintains that arsenic acid produced in the first determination does not interfere with the reaction.

The original amount of chlorine present in the bleach as chloride is obtained by deducting the chloride equivalent in experiments Nos. 1 and 2, from experiment 3.

$$1 \text{ cc.} \frac{N}{10} \text{ potassium thiocyanate} = {\cdot}00971 \text{ grams. NCSK.}$$
$$= {\cdot}00355 \text{ grams. Cl.}$$

II. Bleach Liquors.

Preparation of Mill Stock.—The treatment of bleaching powder with water for the preparation of the stock solution requires some little care in order to obtain the maximum yield of available chlorine. The most economical plan is to extract a considerable weight of powder to ensure that the first solution drawn off has a fairly high density, and to follow with successive washings properly regulated so that these can be added to the first without reducing its density below that required for stock. The final washings of the residues should be utilised for extraction of fresh quantities of bleaching powder.

The method required for adequate washing of bleach residue to obtain a complete extraction without producing large volumes of weak liquor is based upon the principle that a definite volume of water will give a more thorough washing if used in three successive operations than in two. Thus 300 gallons of water will extract more bleach from residues if used successively in three lots of 100 gallons than in two lots of 150 gallons.

The bleaching powder when thrown into the mixing tank should not be stirred more than 20 minutes, which is amply sufficient to produce a maximum density in the first solution. Longer agitation renders the insoluble matter bulky and the time occupied in settling is greatly lengthened. Moreover the residue does not settle down properly, and it is impossible to draw off the strong liquor completely.

That 20 minutes is sufficient is shown by the following experiment :—

Thirty cwt. of bleaching powder was placed in a mixer. The solution was tested at intervals for density and also titrated with N/10 Arsenic.

Time.	Twaddell.	cc. Arsenic for 1 cc. Solution.
10 minutes ...	8.50	7·5
20 ,, ...	9·20	8·1
30 ,, ...	9·25	8·2
40 ,, ...	9·25	8·2
50 ,, ...	9·25	8·2

Importance of Washings.—That the complete extraction of the bleaching powder, and the consequent economy of bleaching depends largely on proper washing and the utilisation of the weak liquor is shown by the appended laboratory trials.

Method.—A bleaching powder previously tested for available chlorine was extracted with successive volumes of water; the solution drawn off, after each washing, was tested for density and chlorine.

Example 1.—Bleaching powder. (33·12 per cent. available chlorine). 1 lb. = 453·6 grams.

Volume of Extract, cc.	Density, Twaddle.	Chlorine in 1 cc. Solution, grams.	Chlorine in total cc. Solution obtained, grams.	Equivalent weight of 33·13 % power, grms.	Percentage of the powder extracted at each stage.
1843	17·0	·05258	96·90	292·6	64·5
1880	6·25	·01902	35·75	107·9	23·8
1650	2·0	·07445	12·28	36·9	8·1
1220	0·5	·00252	3·08	9·3	2·0
1350	0·25	·00096	1·30	3·9	0·8
7943	Av. = 6·00		149·31	450·6	99·2 %

Final Result.—7943 cc. at 6° Twaddel from 453·6 grams.

Litres of bleach solution, per kilo = 17·51

Gallons of bleach solution, per cwt. = 196·00

Example 2.—Bleaching powder (36·0 per cent. available chlorine), 200 grams.

Volume of extract cc.	Density. Twaddell.	cc. of Arsenic to 1 cc. solution.	Chlorine in 1 cc. solution. Grams.	Chlorine in total cc. solution obtained. Grams.	Equivalent weight of 36·0% Power. Grams.	Percentage of the powder extracted at each stage.
1,250	13·25	11·75	·0417	52·14	144·8	72·4
1,250	4·0	3·20	·01136	14·20	39·4	19·7
1,250	1·25	0·94	·0033	4·125	11·4	5·7
3,750	6.16			70·465	195·6	97·8%

Final Result—3,812 cc. at 6° Twaddell from 200 grams.

Litres of bleach solution per kilo. = 19·06.

Gallons ,, ,, ,, cwt. = 213·00.

The practical conclusion to be drawn from these experiments is that the bleaching powder should be extracted three times and the final washings of the grouts or residue should be utilised for extracting fresh powder.

Contents of Bleach Liquor.—The volume of liquor to be obtained from a given weight of powder is readily determined by careful laboratory trials such as those described above.

The following table is useful as showing the quantity of powder required to produce 100 gallons of liquor (adapted from Lunge and Beichofen).

Density. °TW.	Available chlorine. Grams. per litre or lbs. per 100 gallons.	Gallons obtained from 100 lbs. powder.		Pounds of powder to give 100 gallons of liquor.	
		34% powder.	36% powder.	34% powder.	36% powder.
·25	0·70	4860	5143	2.05	1·94
·50	1·40	2430	2571·5	4·10	3·88
1	2·71	1259	1330	7·97	7·53
2	5·58	609	645	16·41	15·50
3	8·48	401	425	24·95	23·56
4	11·44	298	314·5	33·55	31·76
5	14·47	235	248	42·58	40·20
6	17·36	196	208	51·06	48·20
7	20·44	168	176	60·11	56·8
8	23·75	143	151·5	69·85	66·0
9	26·62	128	125	78·30	74·0
10	29·41	116	122·5	87·06	81·7
11	32·63	104	110	96·11	90·8
12	35·81	95	100	105·32	99·5
13	39·10	87	92	115·00	108·6
14	42·31	80	85	124·45	117·5
15	45·70	74·5	78	134·41	126·9
16	48·96	69	73·5	143·80	136·0
17	52·27	65	69	153·73	145·2
18	55·18	61·5	65	162·30	153·3
19	58·40	58	61	171·00	162·2
20	61·50	55·5	58	180·88	171·0

Dilution of Liquors.—A few notes on some approximate calculations respecting dilution which can be utilised in mill practice may be useful, and these are given in the form of examples.

(1.) *A bleach liquor measuring* 100 *gallons at* 10° *Tw. is to be diluted with* 25 *gallons of water. What is the density of the mixture?*

100 gallons of water	= 1000 lbs.		
100 gallons 10° Tw. liquor	= 1000 (lbs.) × 1·050 (sp. gr.)	=	1050 lbs. (wt.)
25 gallons of water	=		250 lbs.
125 gallons of mixture	=		1300 lbs.

125 gallons of mixture = 1300 lbs.
100 gallons of mixture = 1040 lbs. = 1000 × 1·040.
Specific gravity = 1·040 or 8° Tw.

(2.) *How much water must be added to* 250 *gallons of bleach liquor* 14° *Tw. to reduce the density to* 9° *Tw. ?*

vol. lbs. sp. gr.

250 gallons at 14° Tw. = 250 × 10 × 1·070 = 2675 lbs.
x gallons at 9° Tw. = x × 10 × 1·045 = 10·45 x lbs.
Volume of added water = (x − 250) gallons.
Weight of added water = 10 (x − 250) lbs.
Hence 2675 + 10 (x − 250) = 10·45 x.
x. = 389 gallons.

Thus 250 gallons at 14° Tw. give 389 gallons at 9° Tw, and require 139 gallons of water for dilution.

(3.) *Calculate the reduction of density effected by adding varying quantities of water to* 1000 *gallons of bleaching liquor* 20° *Tw. ?*

Original Solution. gallons.	Water added. gallons.	Volume of mixture.	Weight of mixture. lbs.	Specific Gravity of mixture.	Density, Twaddell.
1000	——	1000	11000	1·100	20·0
1000	250	1250	13500	1·080	16·0
1000	500	1500	16000	1·066	13·2
1000	750	1750	18500	0·057	11·4
1000	1000	2000	21000	1·050	10·0
1000	2000	3000	31000	1·033	6·6
1000	3000	4000	41000	1.025	5·0

It will be noticed that the increase in volume is proportional to the reduction in density. From this it follows that

$$\frac{\text{Volume of a solution before dilution}}{\text{Volume of the solution after dilution}} = \frac{\text{Density after diluting.}}{\text{Density before diluting.}}$$

$$\text{that is } \frac{V}{v} = \frac{T}{t} \text{ or } VT = vt,$$

from which obtains the rule:—If v gallons having a density t is is diluted with water till its volume is V, then the density T of the diluted solution is calculated thus :

Multiply the volume v by its density t and divide by the volume V.

This rule can be applied in many ways.

(4). *Certain extracts were obtained by washing bleaching powder.*

1. 1000 gallons 20° Tw. strong liquor.
2. 600 „ 10° Tw. 1st washing.
3. 600 „ 4° Tw. 2nd washing.
4. 300 „ 2° Tw. 3rd washing.
5. 300 „ ½° Tw. 4th washing.

What is the volume and density of the mixture?

The final volume is 2,800 gallons, the density of which has to be calculated.

The various extracts must first be reduced to a comparable condition by calculating the volume of each to some standard density. This may be the highest in the series or any other. Thus 10° Tw. is a convenient standard. Then—

1000 gallons	at	20° Tw.	=	2000 gallons	at 10° Tw.
600 "		10°	=	600 "	10°
600 "		4°	=	240 "	10°
300 "		2°	=	60 "	10°
300 "		½°	=	15 "	10°
2800		t°		2915	10°

The comparative theoretical volume is 2915 gallons at 10° Tw, and the density of the actual volume obtained, viz.: 2800 gallons, is then calculated thus—

$$VT = vt.$$

$$2915 \times 10 = 2800 \times t.$$

$$t° = 10{\cdot}41° \text{ Tw. (density of mixture).}$$

The dilution of bleach liquors with water to give any desired density from 16° Tw. to 1° Tw. can be effected by means of the following table:—

TABLE FOR DILUTION OF BLEACH LIQUOR,

showing gallons of water required to reduce density of 100 gallons of liquor from density D to density d.

Higher density D. Tw.	Lower density d. Tw.											
	12	11	10	9	8	7	6	5	4	3	2	1
16	33·3	45·4	60	77·7	100	128·5	166·6	220	300	433·3	700	1500
15	25·0	36·4	50	66·6	87·5	114·3	150	200	275	400	650	1400
14	16·6	27·3	40	55·5	75	100	133·3	180	250	366·6	600	1300
13	8·3	18·2	30	44·4	62·5	85·7	116·6	160	225	333·3	550	1200
12		9·1	20	33·3	50	71·4	100	140	200	300	500	1100
11			10	22·2	37·5	57·1	83·3	120	175	266·6	450	1000
10				11·1	25	42·8	66·6	100	150	233·3	400	900
9					12·5	28·5	50	80	125	200	350	800
8						14·2	33·3	60	100	166·6	300	700
7							16·6	40	75	133·3	250	600
6								20	50	100	200	500
5									25	66·6	150	400
4										33·3	100	300

Deterioration of Liquor.—The unstable nature of solutions of bleaching powder, and the loss of available cholorine entailed when the liquor is not used under proper conditions is well known to most paper makers, although such depreciations in bleaching value are not always expressed in numerical terms. The following experiment will throw some light on the character and extent of the changes found in ordinary bleach liquor, when stored.

Some fresh bleaching powder was taken, and a solution made by extraction with distilled water, having a strength of 7 degs. Twaddell. Three lots of liquor were put aside under the following conditions:—

A. Sample of clear liquor in stoppered bottle.

B. Sample of liquor in an open vessel, and left exposed, the crust of chalk which quickly formed on the surface being left undisturbed.

C. Sample of liquor in an open vessel, agitated twice a day, at 9 a.m. and 4 p.m.

These solutions were tested once a week, with a standard decinormal solution of arsenic.

TABLE SHOWING CC. OF ARSENIC SOLUTION REQUIRED BY 1 CC. OF THE BLEACH LIQUOR.

Period.	A. Stoppered Bottle.	B. Open Vessel not disturbed.	C. Open Vessel Agitated.
At start ...	7·05	7·05	7·05
After 1st week ...	6·90	6·90	3·90
2nd ,, ...	6·85	6·60	0·40
3rd ,, ...	6·8	4·0	0·27
4th ,, ...	6·8	2·7	0·15

In the case of the bleach liquor preserved in a bottle and kept away from contact with air, the loss of available chlorine is very slight. In the open vessel, where the formation of a crust has prevented continual contact with the air, the reduction of strength is slight after the first two weeks. Probably the rapid fall in the later weeks of the period may be due, in some measure, to the disturbance of the crust in removing samples for titration. In the case of the solution agitated each day the loss of strength is very rapid.

The precise value of these changes are readily determined by reference to the accompanying tables, in which the losses are set out.

TABLE SHOWING AVAILABLE CHLORINE IN 100 CC. OF THE BLEACH SOLUTIONS.

	A Grams.	B. Grams.	C. Grams.
At start ...	2·50	2·50	2·5
After 1 week ...	2·45	2·45	1·38
2 weeks ...	2·43	2·34	0·14
4 weeks ...	2·40	0·96	0·05

TABLE SHOWING THE AVAILABLE CHLORINE EXPRESSED AS LBS. OF NORMAL BLEACHING POWDER PER 100 GALLONS.

	A.	B.	B.
At the start ...	70·5 lbs.	70·5 lbs.	70·5 lbs.
After 1 week ...	69·0	69·0	39·0
2 weeks ...	68·5	66·0	4·0
4 weeks ...	68·0	27·0	1·5

The storage of the bleach liquor in the paper mill usually resembles the conditions of experiment B, and it will be noticed that the depreciation for the first week is very slight indeed.

The principal chemical changes brought about by exposure to air is the disappearance of calcium hypochlorite and the increase of the percentage of calcium chloride, concurrent with the formation of a considerable amount of chalk, more particularly with the sample agitated each day.

The exact composition of the liquors at the end of each week was not determined. But the following details will be of interest in relation to experiments C and A.

TABLE SHOWING CHLORINE IN 100 CC. OF SOLUTION.

	At the start.		After 4 weeks.	
	A.	C.	A.	C.
Chlorine present as Hypochlorite ...	2·50	2.50	2·40	0·05
Chlorine present as Chloride	0·09	0·09	0·12	2·18

III. Oxidation of Cellulose.

THE operation of bleaching by means of Calcium Hypochlorite is a specific instance of oxidation under basic conditions. In practice the action is confined as far as possible to the complete removal of the non-cellulose complex that has survived the hydrolysing action of the particular chemicals used. This resolution may be effected by an alkaline hydrolytic agent Na_2O, as for example, in the Soda and Sulphate processes, or by an acid hydrolysis, as in the Bisulphite process, where the active agent is Sulphurous Acid H_2SO_3.

A normal cellulose is perfectly white and it is only the non-cellulose constituents associated with the carbohydrate forming the compound celluloses, that require the hydrolytic action of an active chemical as a solvent for the various complexes. This hydrolysis however has its limits, and though the fibre is much more resistant to the action of alkali than it is to acid, a point is reached at which the cellulose begins to be attacked and soluble forms of cellulose β cellulose, hydracellulose, etc., are formed, and at the same time the coloured non-cellulose compounds combine more or less again with the cellulose and are fixed upon the fibre. This is clearly seen in "overboiling" a lignocellulose, such as for example the woods with caustic soda when in such cases the product is turned out from the digesters almost black.

It is obvious here that since bleaching involves the oxidation and conversion of these non-cellulose constituents into colourless soluble derivatives, the consumption of bleach would be correspondingly higher than for a properly boiled pulp, and the purified cellulose obtained would be very weak owing to the high percentage of β cellulose. Hence the points to aim at in the preparation of wood pulps where a good colour is required with a minimum consumption of bleach are—

(1) A proper proportion of alkali to the particular wood which it is desired to treat. This is a most important point, for different woods require considerably different amounts of the resolving agent.

(2) Pressure at which the boiling operation is carried out.

(3) The time of the boiling operation.

As an antithesis to an overboiled pulp we have a class of pulps prepared usually by the bisulphite process termed "low-boiled" pulps, in which the presence of the calcium lignone sulphonate and other lime salts is immaterial, and the main consideration is the strength of fibre.

As the name implies, the resolution of the wood substance is not carried forward to the same extent as in a normally boiled wood, so that we have present a relatively large amount of non-cellulose constituents.

For this reason low boiled pulps are used in papers where whiteness of the sheet is not a desideratum, and in point of fact a white sheet cannot be obtained from a low boiled pulp without bleaching, as owing to the presence of phenolic bodies allied with the cellulose the paper rapidly turns pink and finally becomes brown. The former colour is frequently seen in the actual pulp especially on wetting.

Under the action of hypochlorites the coloured non-cellulose constituents of the compound celluloses, and especially the lignocelluloses are, owing to their unsaturated character, essentially more liable to attack than the cellulose proper, and the oxidised acid products so formed being soluble, are removed by washing from the fibre.

The general inertness of cellulose however only applies to the normal cellulose type as represented by cotton, flax, and other bast fibres, and conditions may be arrived at when oxidation is not confined only to the non-cellulose itself. This behaviour under chemical action is comparable to that which takes place naturally in the celluloses of Straw and Esparto where we have direct evidence from their chemical composition and general reactions with Fehling Solution and other reagents not only of an increased amount of oxygen in the complex, but considerable reactivity of certain groups.

When oxidation is carried on to its extreme limits the oxycellulose so formed rapidly disintegrates and is extremely brittle.

There is a considerable amount of doubt as to the exact composition of oxycellulose, but according to several investigators it appears to be a mixture of oxycellulose and hydrocellulose with more or less unaltered cellulose residues, the

latter depending entirely upon the extent of attack by the bleach.

These products of oxidation are soluble in caustic alkali and therefore a determination of the amount of cellulose, or alpha-cellulose as it is termed, that resists the action of mercerising alkali, is an extremely important one in the valuation of a bleached pulp.

A noticeable feature of a pulp that has been more or less attacked in the bleaching (overbleached) is the reversion of colour after standing, loss of strength, and the tendency to become brittle. This must be due to the fact that when once the equilibrium of the cellulose molecule is upset under the treatment, absorption of oxygen continues just as is the case with the natural oxycelluloses Esparto and Straw.

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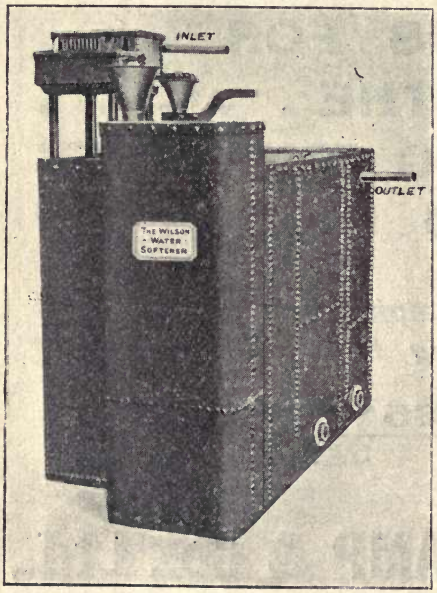

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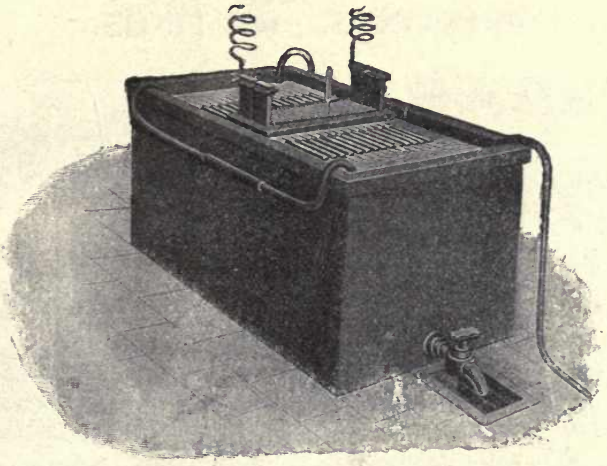

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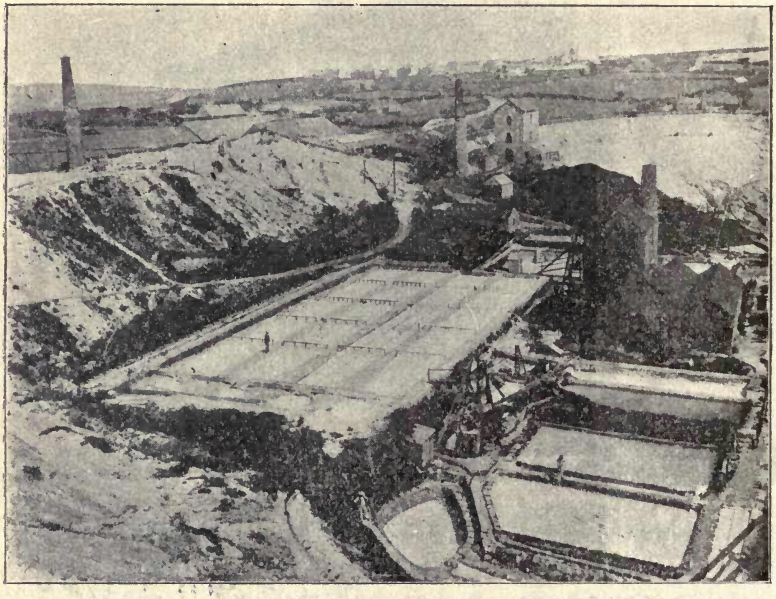

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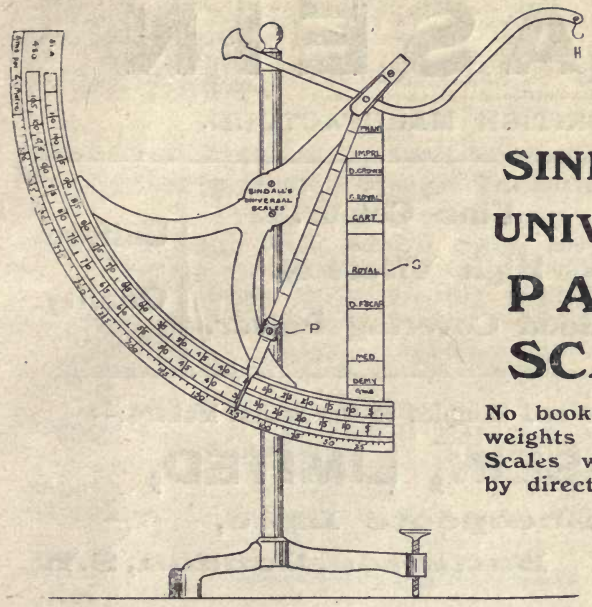

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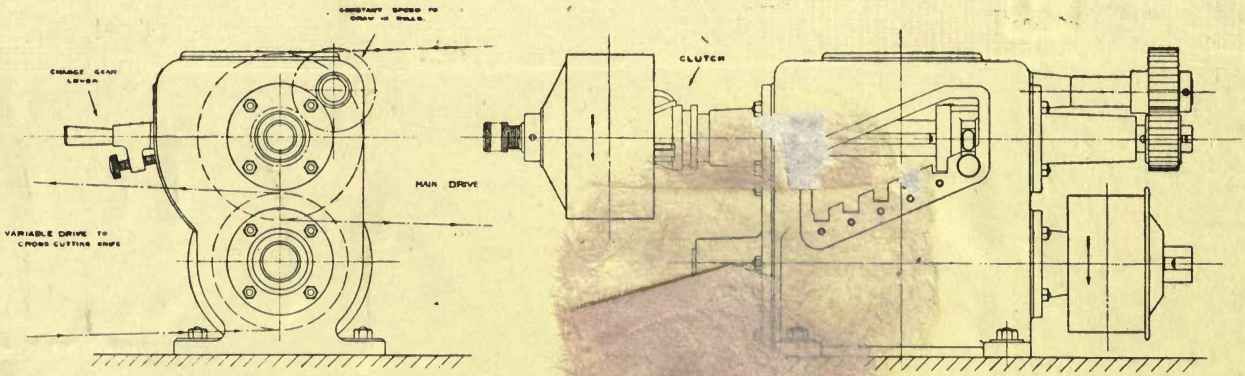

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